JCO

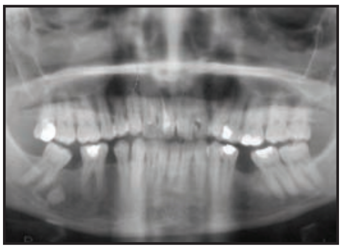
JOURNAL OF CLINICAL ORTHODONTICS

VOLUME XLIII NUMBER 4 APRIL 2009

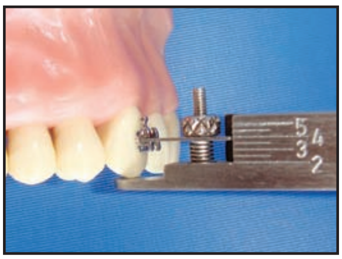
The Cover

The 3D cephalometric analysis described by Dr. Cho is illustrated on this month's cover.

253 JCO Interviews



269 Focal Sclerosis



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DEPARTMENTS

 Journal of Clinical Orthodontics (USPS 802-120, ISSN 0022-3875) is published monthly for $220 per year (U.S. individual rate) by JCO, Inc., 1828 Pearl St., Boulder, CO 80302-5519. Periodicals postage paid at Boulder, CO, and additional mailing office. POSTMASTER: Send address changes to JCO, 1828 Pearl St., Boulder, CO 80302-5519. Phone: (303) 443-1720; e-mail: info@jco-online.com.

Address all other communications to *Journal of Clinical Orthodontics,* 1828 Pearl St., Boulder, CO 80302. Phone: (303) 443-1720; fax: (303) 443-9356; e-mail: info@jco-online.com. Subscription rates: INDIVIDUALS—U.S.A.: $220 for one year, $390 for two years; Canada: $260 for one year, $465 for two years; all other countries: $315 for one year, $545 for two years. INSTITUTIONS—U.S.A.: $310 for one year, $540 for two years; Canada: $345 for one year, $620 for two years; all other countries: $390 for one year, $705 for two years. STUDENTS—U.S.A.: $110 for one year. SINGLE COPY—$21 U.S.A.; $28 all other countries. All orders must be accompanied by payment in full, in U.S. Funds drawn on a major U.S. bank only.

THE EDITOR'S CORNER

A New Dimension in Diagnosis

Cephalometrics has been the diagnostic workhorse of the orthodontic profession since shortly after World War II. Early orthodontic diagnosis had consisted primarily of the analysis of clinical findings and data gathered from diagnostic models. The main drawback of that method was the inability to see what was going on inside the mouth when the patient closed and, even more difficult to determine, what was going on within the underlying skeleton. Although diagnostic models allowed the doctor to view the occlusion from all aspects, the precise skeletal relationships remained a matter of conjecture. But in the last half of the 20th century, the routine application of cephalometric analyses developed by Bolton, Broadbent, Jarabak, Steiner, and others allowed clinicians to study facial growth and treatment outcomes in minute detail. This led to significant advances in both the fundamental science and the day-to-day practice of orthodontics and dentofacial orthopedics.

Since the introduction of cephalometric analysis, its greatest shortcoming has been the same problem faced by cartographers throughout the ages: the projection of three-dimensional structures, such as geographical features or craniofacial anatomy, into two-dimensional representations, such as maps or cephalograms. We have always had to split the difference between bilateral anatomical points such as gonion and orbitale, and we were often left wondering whether variations between the right and left sides were due simply to radiographic projection artifacts or to true asymmetries.

Now, things have changed. The adaptation of cone-beam computed tomography (CBCT) to orthodontics during the last decade has opened the door to more accurate diagnoses of such anatomical problems as impacted teeth and facial asymmetries. Like the early literature on conventional 2D radiography, however, the early papers and books on 3D CBCT have been largely exploratory in nature, describing the technological aspects, practical uses, and clinical potential of this relatively new system. We have all been waiting for an easily applicable 3D cephalometric system analogous to the early 2D analyses—a single, comprehensive measurement scheme that would allow comparisons between individual patients and accepted, standardized norms, as well as for the same patient at different points in time, so that the effects of growth and treatment could be quantitatively analyzed. In short, we have been waiting for an analysis that would do for 3D cephalometry what the Steiner analysis did for 2D cephalometry.

In this issue of JCO, Dr. Heon Jae Cho of the Department of Orthodontics at the University of the Pacific presents just such a system. What will undoubtedly come to be known as the Cho analysis is a thorough, integrated method of evaluating the craniofacial skeleton in all three planes of space, including intermaxillary measurements and vertical, sagittal, and transverse dental measurements. The analysis Dr. Cho describes, based on the 3D volumetric images of one female subject with a Class I malocclusion, is both direct and easily mastered. Using this system, the profession will now be able to develop age-, race-, and gender-specific population norms. This should provide fodder for departmental and resident research projects for years to come. In addition, we are eagerly anticipating the publication of case reports using the Cho analysis in JCO in the near future.

Where do we go from here? As Dr. Ronald Redmond points out in his introduction to Dr. Cho's Cutting Edge article, a 3D analysis is best appreciated, if not in person, then in video format. I can envision the day when all cephalometric patient records will be stored in digital video, so that the full volumetric analyses can be viewed and shared for consultation and research. The next step after that, of course, would be holographic projection with time-lapse coordination—providing a true 4D analysis that could integrate the all-important dimension of time more completely into our diagnostic and treatment-planning procedures. What an exciting time to be an orthodontist! RGK

THE CUTTING EDGE

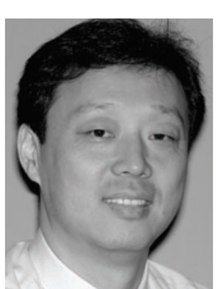
Around the middle of the 20th century, the profession of orthodontics made a giant leap forward. The standard records used for diagnosis and treatment planning were supplemented with cephalometric x-rays, various cephalometric analyses were developed, and, for the first time, growth could be documented through serial cephalograms and superimposition. By the time I completed my orthodontic residency in 1970, it would have been hard to imagine that orthodontic diagnosis could ever have been done without cephalometrics.

This month's Cutting Edge article, I believe, will become the "tipping point" for our next leap forward in understanding the growth and development of the craniofacial complex. Cone-beam computed tomography, relatively new in the orthodontic arena, has been awaiting a true three-dimensional analysis. Dr. Cho's 3D system is a first step in that direction. The aspect of his analysis that may truly revolutionize treatment is the ability to pinpoint minor asymmetries that have sometimes gone undiagnosed in the past.

Dr. Cho's analysis is probably best understood through video, which allows the reference planes, points, and measurements to be visualized through a volume in motion. I wish I were just beginning my orthodontic career, so that I could practice for the next 30-40 years and experience the knowledge and understanding that will come from these cutting-edge tools.

W. RONALD REDMOND, DDS, MS

Dr. Redmond



Dr. Cho

A Three-Dimensional Cephalometric Analysis

For the past few decades, orthodontists and researchers have used two-dimensional lateral cephalometric analysis to study the growth and development of craniofacial structures, to diagnose orthodontic problems, to plan orthodontic treatment, and to evaluate treatment outcomes.[1-15] Because the craniofacial structure is actually a three-dimensional object, however, the traditional lateral cephalometric radiograph provides limited information. The advent of cone-beam computed tomography (CBCT) technology and 3D software has now made it possible for us to visualize, study, and evaluate all three dimensions of the craniofacial structure.

The third dimension missing from the lateral cephalometric radiograph is the transverse plane (the *x*-axis in the 3D coordinate system). Three-dimensional radiographs provide information about not only the transverse plane, but also the intricate interrelationship among the sagittal, frontal, and transverse dimensions. These images are now being used in orthodontic research and treatment. Terajima and colleagues,[16,17] Suri and colleagues,[18] and Kau and Richmond[19] have performed 3D analysis of the craniofacial structures. Garrett and colleagues,[20] Phatouros and Goonewardene,[21] and Ballanti and colleagues[22] have evaluated orthodontic treatment outcomes using 3D images. Still, the task remains of developing a comprehensive, well-organized 3D analysis for the diagnosis of malocclusions and evaluation of orthodontic treatment outcomes.

The present article describes such a system. Measurements were made from a pretreatment 3D radiograph of an adult female patient who presented with normal Class I skeletal and dental relationships and mild incisor crowding. A 3D volumetric image of this patient was obtained using the iCAT cone-beam dental-imaging sys-

Fig. 1 Three landmarks, nasion (N) and the two frontozygomatic (FZ) points, are connected to construct naso-frontozygomatic (NFZ) plane, which is used to reorient axial and coronal axes of images.

tem.* The measurements were performed with InVivoDental software.**

Standardized Reorientation of 3D Images

Proper diagnostic use of a volumetric image for this 3D analysis requires a basic understanding of the Cartesian coordinate system and its three axes (x, y, and z), as well as of the definitions of lines and planes used in the analysis. This 3D system uses the naso-frontozygomatic (NFZ) plane as its cranial base reference plane (Fig. 1). The NFZ plane is constructed from nasion (N) and the right and left frontozygomatic (FZ) points. The coordinate system consists of three axes (x, y, and z) with their origin (0,0,0) registered at N. The x-axis, the transverse axis, is parallel to the FZ line. The y-axis is the anteroposterior axis perpendicular to the FZ line and parallel to the right Frankfort horizontal (R FH) line. The z-axis, the vertical axis, is perpendicular to both the FZ line and the R FH line. Assuming the subject is in an anatomical position, positive values are to the left, posterior, and superior (LPS) to the N point of the subject. Negative values are to the right, anterior, and inferior (RAI) to the N point. The 3D coordinates (x,y,z) of any landmark represent its 3D position relative to N (0,0,0).

To minimize measurement errors from nonstandard head postures, the 3D image is reoriented according to two reference planes, NFZ and FH. This protocol is equivalent to Broadbent's reorientation, using the cephalostat, in his Bolton Study.[23] Using the NFZ plane as the cranial base reference, the coordinates of the N point are set to (0,0,0). Then, y- and z-coordinate values of the right and left FZ points are matched symmetrically by reorienting the coronal and axial axes of the 3D image (Fig. 2). The FH plane is used to reorient the head in the sagittal plane (Fig. 3).

Direct vs. Projected Measurements

This 3D analysis requires many angular or linear measurements to be made on a projected plane, rather than being measured directly in three-dimensional space. For example, the facial line angle is best evaluated when it is projected on the sagittal plane, since the purpose of this angular measurement is to assess the anteroposterior position of the mandible relative to the cranial base. When the facial line angle for a patient with a severe mandibular asymmetry is evaluated, the direct angular measurement will actually show a smaller value than the projected measurement. This is because the direct measurement is affected by the transverse position of the asymmetrical chin, whereas the facial line angle should actually measure the anteroposterior mandibular position irrespective of transverse mandibular asymmetry.

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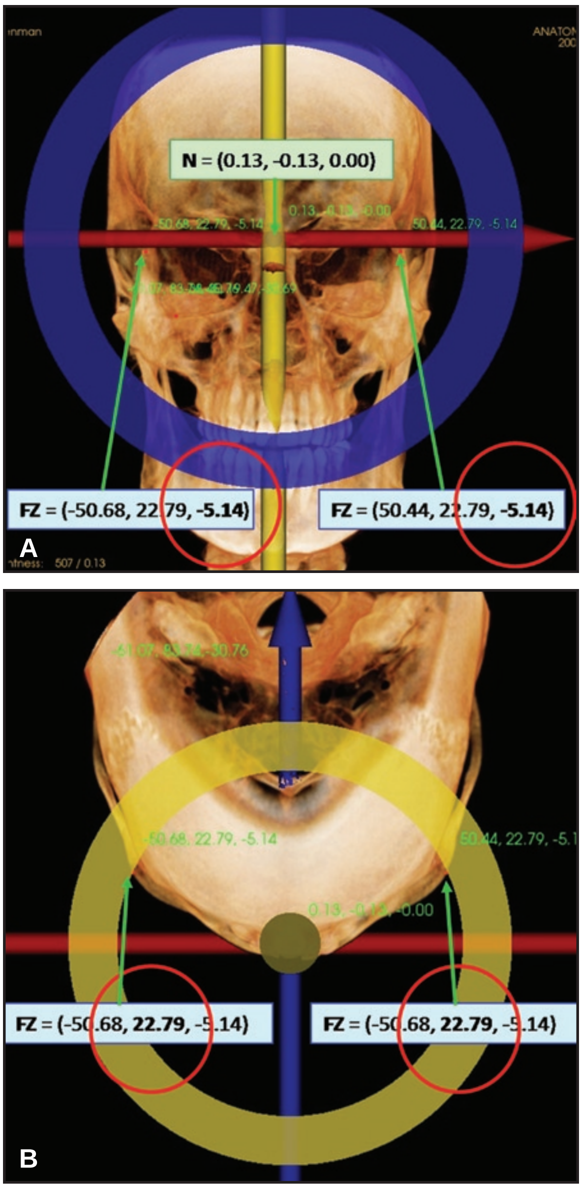

Fig. 2 A. Reorientation of three-dimensional image in frontal plane. Nasion is set as close to (0,0,0) as possible, and *z*-coordinates of right and left FZ points are matched symmetrically. B. Reorientation of 3D image in axial plane, with *y*-coordinates of FZ points matched symmetrically.

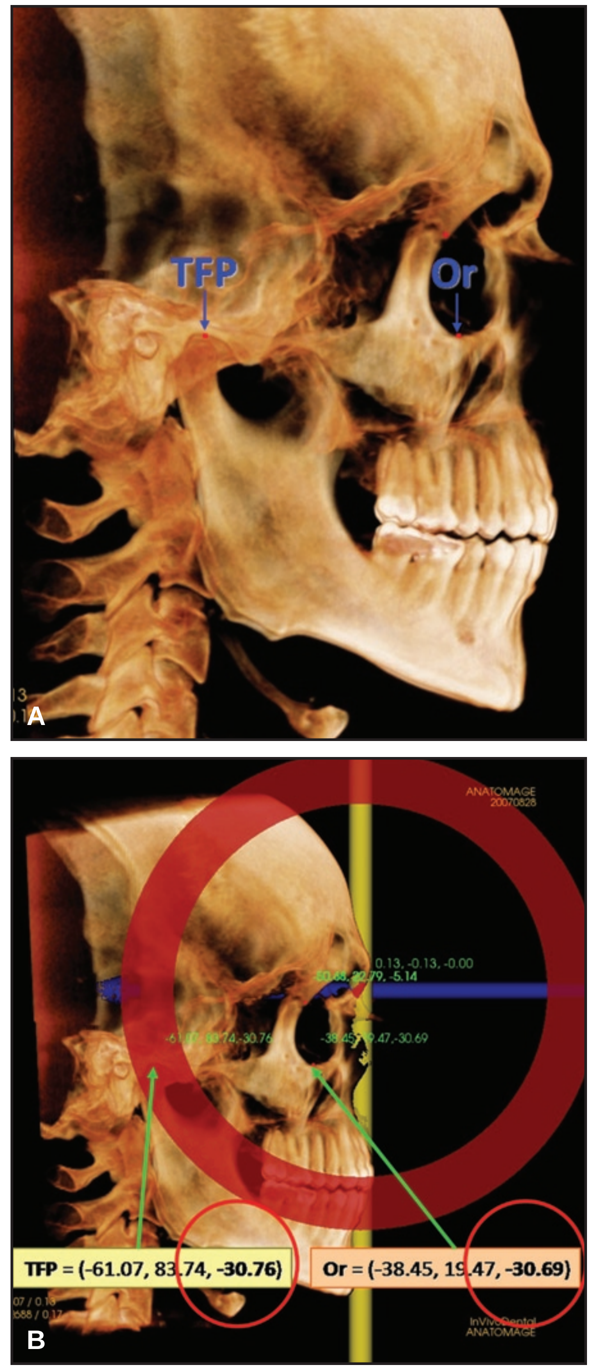

Fig. 3 A. Frankfort horizontal (FH) plane constructed using right and left temporal-fossa points (TFP) and orbitale (Or). B. Skull reoriented in sagittal plane using FH plane, with *z*-coordinates of two landmarks set as close as possible.

Skeletal Landmarks

Cranial Base Landmarks (RL = right and left)

N (nasion): the middle point of the frontonasal suture in the frontal plane

RL FZP (frontozygomatic point): the intersection of the frontozygomatic suture and the inner rim of the orbit in the frontal plane

Sella: the midpoint of the pituitary fossa in the sagittal plane; the midline point in the axial plane

RL Or (orbitale): the most inferior point of the orbital rim in the frontal plane

RL Po (porion): the most superior point of the external auditory meatus

RL TFP (temporal-fossa point): the most superior point of the inferior zygomatic arch border, above the condylar head as seen from the sagittal perspective; the most lateral landmark in the submental-vertex view

Maxillary Landmarks

ANS (anterior nasal spine): the most anterior point of the premaxillary bone in the sagittal plane

PNS (posterior nasal spine): the most posterior point of the palatine bone in the sagittal plane

A point: the deepest point in the anterior outline of the maxilla between supradentale and ANS in the sagittal plane

RL KRP (key ridge point): the most inferior point of the key ridge in the sagittal plane

RL MxBP (maxillary basal point): the point in the lateral outline of the maxilla at which the lateral surfaces of the maxilla turn into the inferior surfaces of the maxillary zygomatic processes in the frontal plane

Mandibular Landmarks

B point: the deepest point in the anterior outline of the mandible between infradentale and pogonion in the sagittal plane

Pog (pogonion): the most anterior point in the mandibular chin area in the sagittal plane

Me (menton): the most inferior point in the middle of the mandibular chin in the frontal plane; the deepest point in the mental depression in the submental-vertex view

RL Go (gonion): the point in the inferoposterior outline of the mandible at which the surface turns from the inferior border into the posterior border in the sagittal plane

RL condylar point: the tip of the mandibular condyle

RL CP (coronoid process) point: the tip of the coronoid process in the sagittal plane

(continued on next page)

Landmark Identification

Although this 3D analysis includes many skeletal and dental landmarks established in previous 2D analyses,[1-15,24,25] some new landmarks are proposed. Landmark location can vary on 2D images, raising the issue of reliability.[26-28] Muramatsu and colleagues evaluated the reproducibility of 19 landmarks on 3D computed tomographic (CT) images.[29] Basion had the smallest confidence ellipse area in all planes, indicating high reproducibility. In general, the size of the ellipse of a specific landmark increased with the slice thickness, but additional studies may be needed to evaluate more landmarks on 3D CT images.

Periago and colleagues compared linear measurements of cephalometric landmarks made on CBCT-derived 3D volumetric surface renderings obtained from direct measurements of a human skull, using Dolphin 3D*** software.[30] Although they found statistically significant differences for many of the measurements, they stated that the 3D image measurements were sufficiently accurate for craniofacial analysis. Lagravère and colleagues compared measurements from CBCT images with those taken from a coordinate measuring machine, which they considered the "gold standard".[31] They reported that the coordinate intraclass correlation coefficient between the two measurement methods was almost perfect, and that the CBCT machine produced a 1:1 image-to-reality ratio. Habersack and colleagues noted that multislice CT images can be valuable in visualizing skeletal effects on the midpalatal sutures and adjacent sutures.[32] They also found that precise 3D location of tooth positions was feasible.

The landmarks listed on these two pages are used to make the measurements required for the 3D cephalometric analysis.

***Dolphin Imaging & Management Solutions, 9200 Eton Ave., Chatsworth, CA 91311; www.dolphinimaging.com.

Dental Landmarks

Maxillary Dental Landmarks

RL U1CP (maxillary central incisor crown point): the midpoint of the incisal edge of the maxillary central incisor

RL U1RP (maxillary central incisor root point): the tip of the root of the maxillary central incisor

RL U3CP (maxillary canine crown point): the tip of the crown of the maxillary canine

RL U3RP (maxillary canine root point): the tip of the root of the maxillary canine

RL U6CP (maxillary first molar crown point): the tip of the mesiobuccal cusp of the maxillary first molar crown

RL U6RP (maxillary first molar root point): the tip of the mesiobuccal root of the maxillary first molar

Mandibular Dental Landmarks

RL L1CP (mandibular central incisor crown point): the midpoint of the incisal edge of the mandibular central incisor

RL L1RP (mandibular central incisor root point): the tip of the root of the mandibular central incisor

RL L3CP (mandibular canine crown point): the tip of the crown of the mandibular canine

RL L3RP (mandibular canine root point): the tip of the root of the mandibular canine

RL L6CP (mandibular first molar crown point): the tip of the mesiobuccal cusp of the mandibular first molar crown

RL L6RP (mandibular first molar root point): the tip of the mesiobuccal root of the mandibular first molar

Reference Lines

FZ line: formed by RL FZP

RL NFZ line: formed by connecting N and RL FZP, projected onto the sagittal plane

R FH line: formed by connecting R Po or R TFP and R Or

Facial line: formed by N and Pog

MxS (maxillary sagittal) line: formed by ANS and PNS

MxF (maxillary frontal) line: formed by RL MxBP

R MdS (mandibular sagittal) line: formed by R Go and Me

L MdS line: formed by L Go and Me

MdF (mandibular frontal) line: formed by RL Go

MxFO (maxillary frontal occlusal) line: formed by connecting RL U6CP in the frontal plane

MdFO (mandibular frontal occlusal) line: formed by connecting RL L6CP in the frontal plane

MxSO (maxillary sagittal occlusal) line: the line at the intersection of the MxO (maxillary occlusal) and MxS planes

MdSO (mandibular sagittal occlusal) line: the line at the intersection of the MdO (mandibular occlusal) and MdS planes

Reference Planes

NFZ plane: anterior cranial base, established by three skeletal landmarks, RL FZP and N

R FH plane: established by RL Po (or RL TFP) and R Or

Midsagittal plane: perpendicular to both the NFZ plane and the frontal plane passing through N

Frontal plane: perpendicular to the NFZ plane passing through RL FZP

Maxillary plane: includes ANS and PNS, parallel to the MxF line (inter-MxBP line)

Mandibular plane: formed by Me and RL Go

MxS plane: perpendicular to the maxillary plane passing through ANS and PNS

MdS plane: perpendicular to the mandibular plane passing through Pog and mid-Go

MxF plane: perpendicular to the maxillary plane passing through RL MxBP

MdF plane: perpendicular to the mandibular plane passing through RL Go

RL maxillary oblique planes: obtained by a 45° rotation of the MxS plane in the horizontal plane

RL mandibular oblique planes: obtained by a 45° rotation of the MdS plane in the horizontal plane

MxO plane: established by three maxillary dental points, R U1CP and RL U6CP

MdO plane: established by three mandibular dental points, R L1CP and RL L6CP

Occlusal plane: formed by bisecting the MxO and MdO planes

TABLE 1
SKELETAL ANTEROPOSTERIOR ANALYSIS

Measurement	Value	Type of Measurement
A(*y*)	1.0mm	Projected (sagittal plane)
B(*y*)	6.0mm	Projected (sagittal plane)
B(*y*)–A(*y*)	7.5mm	Projected (sagittal plane)
SNA	81.5°	Projected (sagittal plane)
SNB	76.5°	Projected (sagittal plane)
ANB	5.0°	Projected (sagittal plane)
Wits appraisal	−2.0mm	Projected (sagittal plane)
Pog(*y*)	2.5mm	Projected (sagittal plane)
Facial line angle (FH-NPog)	92.0°	Projected (sagittal plane)
MxL (ANS-PNS)	47.0mm	Direct
R MdL (R condylar point-Pog)	118.5mm	Direct
L MdL (L condylar point-Pog)	118.0mm	Direct
R MdBL (R Go-Pog)	82.0mm	Direct
L MdBL (L Go-Pog)	81.5mm	Direct

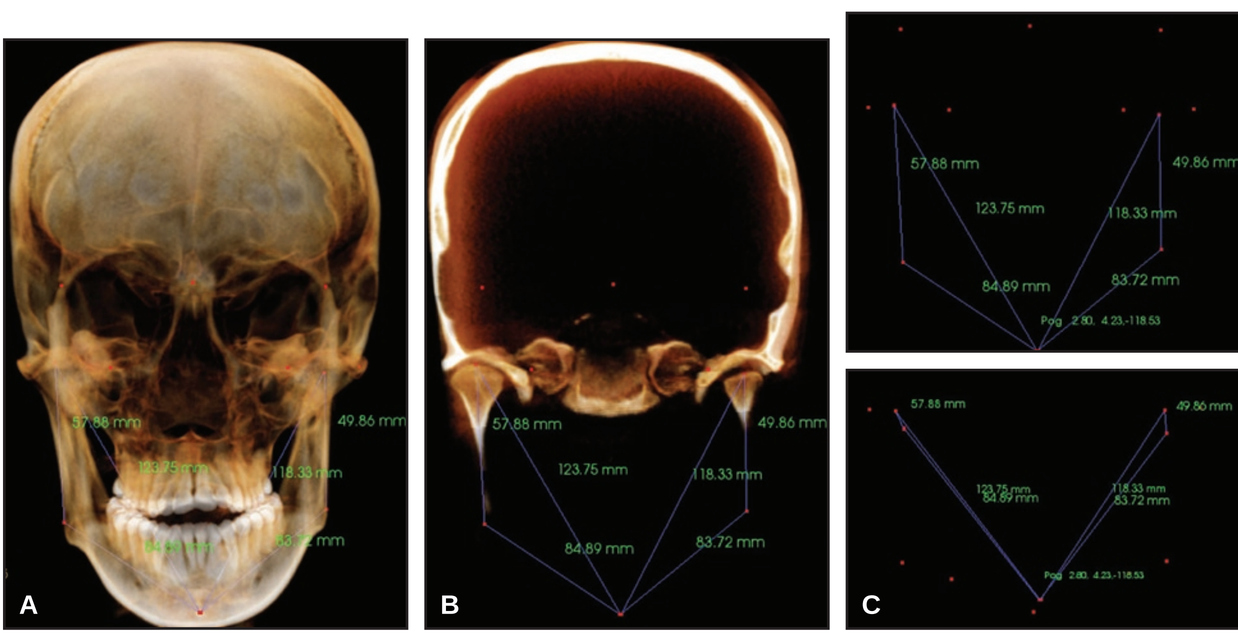

Fig. 4 A. Mandibular lengths—right and left ramal height (RH) and right and left body length (BL)—used to demonstrate mandibular asymmetry. B. Ramal height measured from middle of superior surface of condylar head. C. Mandibular asymmetry demonstrated after cropping of skull surface.

Skeletal Analysis

Most lateral cephalometric analyses use sella-nasion as the anterior cranial base reference line. Sella is defined as the midpoint of the concavity of the sella turcica. On a standard lateral cephalometric radiograph, it can be located fairly reliably from a 2D perspective of a point within a 3D structure. On a volumetric image, however, it can be a problem to locate a landmark that represents the midpoint of a concavity, rather than a physical structure, in three planes of space. Therefore, the NFZ plane is a more reliable reference structure in 3D analysis, since the FZ points are visible

TABLE 2
SKELETAL VERTICAL ANALYSIS

Measurement	Value	Type of Measurement
R TFP(*z*)	27.0mm	Projected (frontal plane)
L TFP(*z*)	26.0mm	Projected (frontal plane)
R Or(*z*)	29.5mm	Projected (frontal plane)
L Or(*z*)	28.5mm	Projected (frontal plane)
ANS(*z*)	52.0mm	Projected (sagittal plane)
PNS(*z*)	49.0mm	Projected (sagittal plane)
R MxBP(*z*)	53.0mm	Projected (frontal plane)
L MxBP(*z*)	53.0mm	Projected (frontal plane)
MxS line angle	3.5°	Projected (sagittal plane)
Me(*z*)	116.5mm	Projected (frontal plane)
R Go(*z*)	87.0mm	Projected (frontal plane)
L Go(*z*)	88.0mm	Projected (frontal plane)
R MdS line angle	26.5°	Projected (sagittal plane)
L MdS line angle	26.0°	Projected (sagittal plane)
R MdRH	62.0mm	Direct
L MdRH	62.0mm	Direct
R GA	116.0°	Direct
L GA	116.0°	Direct
LFH (ANS-Me)	66.5mm	Direct

surface landmarks on the 3D image and components of the anterior cranial base.

Skeletal Anteroposterior Analysis (Table 1)

Three-dimensional analysis is similar to 2D analysis in terms of landmark location and anteroposterior evaluation of the maxillomandibular structures.

Maxilla and Mandible: A(*y*), B(*y*), Pog(*y*). The maxilla is related to the NFZ plane by the value of the *y*-coordinate at A point A(*y*), whereas the mandible is assessed at B(*y*) and Pog(*y*).

Maxilla and Mandible: SNA, SNB, Facial Line Angle. The SNA and SNB angles are projected onto the sagittal plane.[6] Historically, A and B points have been used to assess the sagittal position of the jaws, but the usefulness of these two structural points is limited by their dentoalveolar position and origin. ANS and Pog are preferable because they are structural landmarks representing the basal bones of the maxilla and mandible, respectively. The facial line angle, an angle formed by the FH line and the facial line (NPog) projected onto the sagittal plane, represents the anteroposterior position of the mandible relative to the cranial base.[5]

Intermaxillary Relationship: B(*y*)–A(*y*), ANB. The interrelationship of the maxilla and the mandible is the difference between the *y*-coordinate values of B point and A point, B(*y*)–A(*y*). A larger positive value indicates a more anterior position of the maxilla in relation to the mandible, or a Class II skeleton, whereas a negative value suggests a Class III skeleton. The ANB angle is another measurement of the intermaxillary relationship.[6]

Wits Appraisal. This is the linear distance between AO and BO projected onto the sagittal plane. AO and BO are the perpendicular projections from A point and B point, respectively, to the occlusal plane.[11-12]

Maxillary Length: MxL. Maxillary length (MxL) is the distance between ANS and PNS.

Mandibular Lengths: RL MdL. Right and left mandibular lengths (RL MdL) are linear distances obtained by direct measurements from RL condylar point to Pog (Fig. 4).[9]

Mandibular Body Lengths: RL MdBL. Right and left mandibular body lengths (RL MdBL) are determined by the linear distance from RL Go to Pog (Fig. 4). Any differences in the values between RL MdBL indicate an intramandibular component of the mandibular asymmetry. Determining the underlying etiology is essential for proper diagnosis and treatment planning.

Skeletal Vertical Analysis (Table 2)

FH Lines: RL TFP(*z*), RL Or(*z*). TFP can be used instead of Po to orient the FH lines (Fig. 3A). Locating Po is challenging in 3D images because of the limited volume that 3D CBCT hardware can include in its field of view. The external auditory meatus is a fan-shaped funnel, and even a slight change in vertical position may result in a significant difference in its transverse position. When fully intact in the volumetric image, however, Po can be used as a posterior reference point for the FH plane. The RL TFP represent the base of the cranium on the temporal bone, where the condylar heads articulate. The vertical position of the RL TFP with respect to the NFZ plane in the vertical axis is evaluated using the *z*-coordinate values of RL TFP. These values can be compared to identify a vertical asymmetry between the bilateral cranial base structures (the temporomandibular fossae). The *z*-coordinate values of RL Or are compared to assess any asymmetry in their vertical positions. For convenience, unless a major discrepancy exists between RL FH lines, R FH can be used as a reference line.

Maxilla: ANS(*z*), PNS(*z*). The *z*-coordinates of ANS and PNS indicate the maxillary vertical dimension from the anterior and posterior aspects of the maxilla, respectively.

Maxilla: RL MxBP(*z*). Any difference between the two *z*-coordinates of RL MxBP will show a bilateral vertical asymmetry in the maxilla. The degree of vertical deficiency or excess can thus be accurately determined in both the frontal and sagittal planes.

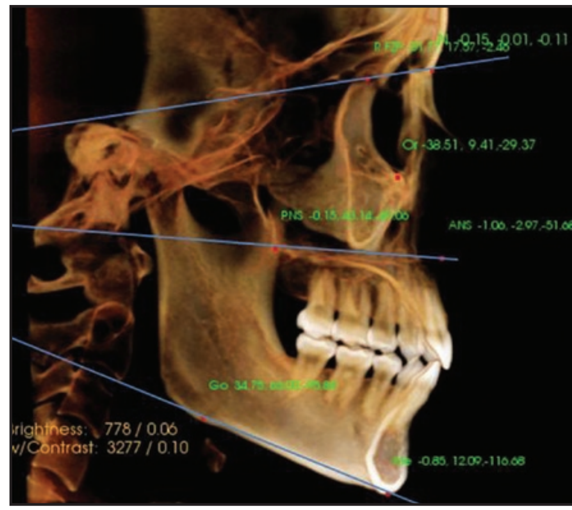

Fig. 5 Maxillary sagittal (MxS) line and mandibular sagittal (MdS) line angles.

Maxilla: MxS Line Angle. In the sagittal plane, the angle formed by the NFZ line and the MxS line determines the degree of divergence of the maxilla relative to the NFZ plane (Fig. 5). This MxS line angle,[7] is projected onto the sagittal plane.

Mandible: Me(*z*), RL Go(*z*). The vertical position of the mandible relative to the NFZ plane is evaluated by the absolute values of the *z*-coordinates of three skeletal points: RL Go and Me. A difference between the *z*-coordinate values of RL Go is a good indication of a vertical asymmetry in the mandible. On the other hand, the cranial base and the maxilla may also contribute to, or be the underlying cause of, the observed mandibular asymmetry. The true etiology of the asymmetry can be determined by evaluating the position of the cranial base by means of RL TFP, the maxilla, and the mandible. Thus, determining the values of the *x*-, *y*-, and *z*-coordinates of RL TFP and RL MxBP enables the clinician to assess any contribution of the cranial base or maxilla to the mandibular asymmetry.

Mandible: RL MdS Line Angles. Recall that RL Go and Me form the RL MdS lines. Using these structural lines, the divergence of the mandible relative to the NFZ plane is determined from the

TABLE 3
SKELETAL TRANSVERSE ANALYSIS

Measurement	Value	Type of Measurement
R FZP(*x*)	51.0mm	Projected (frontal plane)
L FZP(*x*)	50.5mm	Projected (frontal plane)
CBW (R FZP−L FZP)	101.5mm	Projected (frontal plane)
R TFP(*x*)	−62.0mm	Projected (frontal plane)
L TFP(*x*)	60.5mm	Projected (frontal plane)
ITFPW	122.0mm	Projected (frontal plane)
ANS(*x*)	−1.0mm	Projected (frontal plane)
PNS(*x*)	0.0mm	Projected (frontal plane)
R MxBP(*x*)	−32.5mm	Projected (frontal plane)
L MxBP(*x*)	30.0mm	Projected (frontal plane)
MxBW (R MxBP−L MxBP)	63.0mm	Projected (Mx frontal)
MxF line angle	0.0°	Projected (frontal plane)
Pog(*x*)	−0.5mm	Projected (frontal plane)
R Go(*x*)	−43.0mm	Projected (frontal plane)
L Go(*x*)	41.0mm	Projected (frontal plane)
MdBW (R Go−L Go)	84.0mm	Projected (Md frontal)
MdF line angle	0.5°	Projected (frontal plane)
MxMdF line angle	0.5°	Projected (frontal plane)
Mx/CB WR	0.62	Direct
Md/CB WR	0.83	Direct
Mx/Md WR	0.75	Direct

intersection of the NFZ line with the corresponding RL MdS lines in the sagittal plane (Fig. 5). The RL MdS line angles[5-7,15] are projected onto the sagittal plane. A difference between these angles indicates a combination of extramandibular and intramandibular components.

Mandible: RL MdRH, RL GA. The right and left mandibular ramal heights (RL MdRH) are measurements of the linear distance from R Go to R condylar point and L Go to L condylar point, respectively (Fig. 4A,B). Any difference between RL MdRH may indicate an intramandibular component of the mandibular asymmetry. The right and left gonial angles (RL GA) are direct measurements of the inside angles formed by the ramus lines and the MdS lines.[10]

Lower Facial Height. Lower facial height (LFH) is the linear distance between ANS and Me.[9,13]

Skeletal Transverse Analysis (Table 3)

The skeletal transverse analysis compares the right and left absolute values along the *x*-axis to assess symmetry, as well as the actual body width between the right and left points.

Cranial Base: RL FZP(*x*), RL TFP(*x*). The *x*-coordinates of FZP and TFP indicate the transverse dimension of the cranial base in both the frontal and axial planes. Any difference between the *x*-coordinate values of RL FZP indicates a transverse asymmetry in the cranial base. The values of the *x*-, *y*-, and *z*- coordinates of RL TFP provide information for appraisal of any asymmetry between the bilateral condylar housings. This is useful in determining whether a mandibular asymmetry is due to an extramandibular factor, such as differences in the RL TFP positions, or to intramandibular anatomical factors.

Fig. 6 Cranial base widths: inter-FZP or cranial base width (CBW) and inter-TFP width (ITFPW).

Cranial Base Width: CBW, ITFPW. The inter-FZP or cranial base width (CBW) is the linear distance between the RL FZP projected onto the frontal plane (Fig. 6). The inter-TFP width (ITFPW) is the linear distance between RL TFP projected onto the frontal plane.

Maxilla: ANS(*x*), PNS(*x*). The *x*-coordinate values of ANS and PNS provide information about the transverse position of the maxilla.

Maxilla: RL MxBP(*x*). The *x*-coordinate values of the RL MxBP provide information about the transverse position of the posterior maxilla on both sides.

Maxillary Base Width: MxBW. The maxillary base width (MxBW) is the linear distance between the RL MxBP projected onto the MxF plane.

Maxilla: MxF Line Angle. An asymmetry of the maxilla can also be evaluated using this angle. Any angle formed between the FZ line (not the NFZ plane) and the MxF line projected onto the frontal plane determines the degree of canting of the maxillary basal bone relative to the FZ line (Fig. 7). This is known as the MxF line angle. An absolute value greater than 0° indicates a cant of the maxillary basal bone relative to the FZ line. The

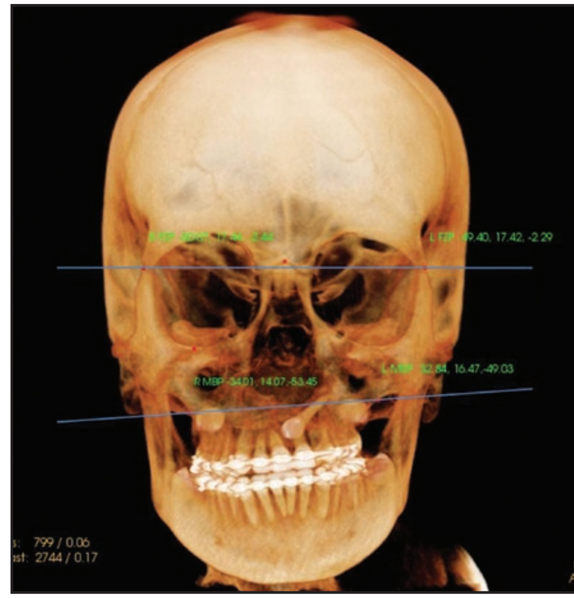

Fig. 7 Maxillary frontal (MxF) line angle.

value is positive when the base of the angle is to the subject's right and diverges to the left, and negative in the opposite situation.

Mandible: Pog(*x*). The *x*-coordinate value of Pog provides information about the transverse position of the anterior mandible.

Mandible: RL Go(*x*). The *x*-coordinate values of RL Go provide information about the transverse position of the posterior mandible. Any difference between these two values is a good indication of a transverse asymmetry in the mandible.

Mandibular Base Width: RL MdBW. The mandibular base width (MdBW) is measured by the linear distance between RL Go projected onto the MdF plane.

Mandible: MdF Line Angle. Any angle formed between the FZ line and the MdF line in the frontal plane determines the degree of canting of the mandibular basal bone relative to the FZ line. This is known as the MdF line angle. An absolute value greater than 0° indicates a cant of the mandibular basal bone relative to the FZ line. The value is positive when the base of the angle is to the subject's right and diverges to the left, and negative in the opposite situation. A difference between RL MdF line angles indicates a combination of extramandibular and intramandibular components.

TABLE 4
DENTAL ANTEROPOSTERIOR ANALYSIS

Measurement	Value	Type of Measurement
R U1SI	114.0°	Projected (Mx sagittal)
L U1SI	106.5°	Projected (Mx sagittal)
R U1SP	2.5mm	Projected (Mx sagittal)
L U1SP	2.5mm	Projected (Mx sagittal)
R L1SI	97.0°	Projected (Md sagittal)
L L1SI	96.5°	Projected (Md sagittal)
R L1SP	6.5mm	Projected (Md sagittal)
L L1SP	6.0mm	Projected (Md sagittal)
R U3SI	98.5°	Projected (R Mx oblique)
L U3SI	94.5°	Projected (L Mx oblique)
R U3SP	16.0mm	Projected (Mx sagittal)
L U3SP	16.5mm	Projected (Mx sagittal)
R L3SI	90.0°	Projected (R Md oblique)
L L3SI	85.0°	Projected (L Md oblique)
R L3SP	7.0mm	Projected (Md sagittal)
L L3SP	7.5mm	Projected (Md sagittal)
R U6SI	95.0°	Projected (Mx sagittal)
L U6SI	89.5°	Projected (Mx sagittal)
R U6SP	3.5mm	Projected (Mx sagittal)
L U6SP	3.0mm	Projected (Mx sagittal)
R L6SI	87.0°	Projected (Md sagittal)
L L6SI	89.0°	Projected (Md sagittal)
R L6SP	21.5mm	Projected (Md sagittal)
L L6SP	22.5mm	Projected (Md sagittal)
L1:Pog	6.5	Projected (sagittal plane)

Intermaxillary Relationship: MxMdF Line Angle. Any angle formed between the MxF line and the MdF line in the frontal plane determines the degree of canting of the mandibular basal bone relative to the maxillary basal bone. This is known as the maxillomandibular frontal (MxMdF) line angle. The value is positive when the base of the angle is to the subject's right and diverges to the left, and negative in the opposite situation.

Maxillary/Mandibular Base to Cranial Base Width Ratios: Mx/CB WR, Md/CB WR. The ratios between MxBW/MdBW and CBW (Mx/CB WR and Md/CB WR) in normal skeletons will serve as good references for the management of patients with significant transverse discrepancies.

Maxillary Base to Mandibular Base Width Ratio: Mx/Md WR. The ratio between MxBW and MdBW (Mx/Md WR) is used to analyze the intermaxillary transverse relationship. Within each jaw, the ratio between the basal bone width and the intermolar width, as defined in the dental transverse analysis, provides valuable information about the transverse development of the dentition.

Dental Analysis

Dental Anteroposterior Analysis (Table 4)

Like the 3D skeletal anteroposterior analysis, the 3D dental anteroposterior analysis is similar to that of any 2D cephalometric system. The major difference is that in a lateral cephalometric radiograph, superimposition of the images makes it impossible to evaluate the teeth individually.

Fig. 8 Maxillary central incisor sagittal inclination (U1SI).

Because a unilateral evaluation of the dentition is usually sufficient for both the right and left dental structures, the analysis described below is taken from the right dental points for convenience. Bilateral evaluation is recommended in cases where significant asymmetries are suspected.

Maxillary Incisor: RL U1SI, RL U1SP. Both angular and linear measurements are used to evaluate incisor position. The maxillary central incisor sagittal inclination (U1SI) is the lingual angle between the long axis of the maxillary central incisor and the MxS line, projected onto the MxS plane (Fig. 8). The maxillary central incisor sagittal position (U1SP) is the perpendicular linear distance from U1CP to the NA line, projected onto the MxS plane.[6]

Mandibular Incisor: RL L1SI, RL L1SP. The mandibular central incisor sagittal inclination (L1SI, or IMPA) is the lingual angle formed by the intersection of the long axis of the mandibular central incisor and the R or L MdS line, projected onto the MdS plane.[5,8] The mandibular central incisor sagittal position (L1SP) is the perpendicular linear distance from the L1CP to the NB line, projected onto the MdS plane.[6]

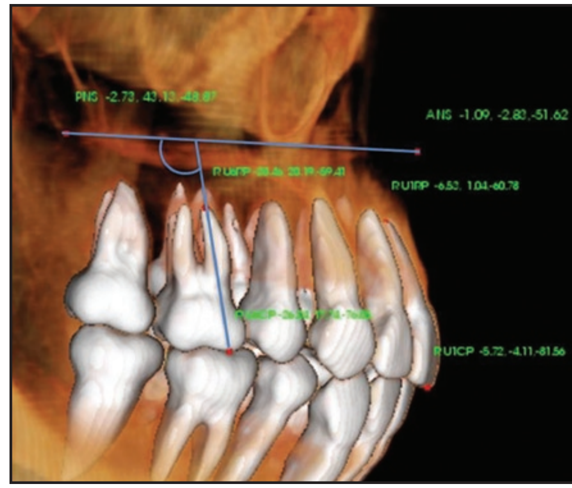

Fig. 9 Maxillary molar sagittal inclination (U6SI).

Maxillary Canine: RL U3SI, RL U3SP. The maxillary canine sagittal inclination (U3SI) is the distal angle between the long axis of the maxillary canine and the maxillary plane, projected onto the ipsilateral maxillary oblique plane. The canine root inclination is best evaluated in the oblique plane, because changes in inclination tend to be underestimated in the sagittal plane. The maxillary canine sagittal position (U3SP) is the difference between the *y*-coordinate values of U3CP and MxBP, projected onto the MxS plane.

Mandibular Canine: RL L3SI, RL L3SP. The mandibular canine sagittal inclination (L3SI) is the distal angle between the long axis of the mandibular canine and the R or L MdS line, projected onto the ipsilateral mandibular oblique plane. The mandibular canine sagittal position (L3SP) is the difference between the *y*-coordinate values of L3CP and Pog, projected onto the MdS plane.

Maxillary Molar: RL U6SI, RL U6SP. The maxillary molar sagittal inclination (U6SI) is the distal angle formed by the long axis of the maxillary first molar (the axis connecting the mesiobuccal cusp and root tips) and the R or L MxS line, projected onto the MxS plane (Fig. 9). The differ-

TABLE 5
DENTAL VERTICAL ANALYSIS

Measurement	Value	Type of Measurement
R U1VD	30.0mm	Direct
L U1VD	30.5mm	Direct
R U6VD	23.5mm	Direct
L U6VD	23.0mm	Direct
R L1VD	26.0mm	Direct
L L1VD	26.5mm	Direct
R L6VD	35.5mm	Direct
L L6VD	35.5mm	Direct
MxFO line angle	0.0°	Projected (Mx frontal)
MdFO line angle	0.5°	Projected (Md frontal)
MxSO line angle	12.5°	Projected (Mx sagittal)
MdSO line angle	15.0°	Projected (Md sagittal)

ence between the *y*-coordinate values of MxBP and the ipsilateral U6CP is the maxillary molar sagittal position (U6SP), which indicates the anteroposterior position of the maxillary first molar crown within the maxilla.

Mandibular Molar: RL L6SI, RL L6SP. The mandibular molar sagittal inclination (L6SI) is the distal angle formed by the long axis of the mandibular first molar (the axis connecting the mesiobuccal cusp tip and mesial root tip) and the R or L MdS line, projected onto the MdS plane. The difference between the *y*-coordinate values of Pog and L6CP is the mandibular molar sagittal position (L6SP), which indicates the anteroposterior position of the mandibular first molar crown within the mandible.

Lower Incisor to Pogonion Ratio: L1:Pog. The L1:Pog ratio compares the linear measurements of R L1CP and Pog from the NB line, projected onto the sagittal plane. This measurement is useful because the position of the mandibular incisor relative to Pog is important for facial balance and esthetics.

Dental Vertical Analysis (Table 5)

The relationship of the vertical position of the dentition to the apical base is readily seen in a 3D volumetric image. Vertical linear measurements reflect the amount of vertical development of the dentoaveolar process. Like the dental anteroposterior analysis, the dental vertical analysis can be performed bilaterally if necessary.

Maxillary Dentition: RL U1VD, RL U6VD. The maxillary incisor vertical development (U1VD) is the perpendicular distance from U1CP to the maxillary plane. The maxillary molar vertical development (U6VD) is the perpendicular distance from U6CP to the maxillary plane (Fig. 10).

Mandibular Dentition: RL L1VD, RL L6VD. The mandibular plane is used to measure the vertical development of the mandibular central incisors and first molars. Similar to U1VD, the mandibular incisor vertical development (L1VD) is the perpendicular distance from L1CP to the mandibular plane. The mandibular molar vertical development (L6VD) is the perpendicular distance from L6CP to the mandibular plane.

Occlusal Plane Canting: MxFO Line Angle, MdFO Line Angle. The MxFO line angle is the intersection, if any, of the MxFO line with the MxF line, projected onto the MxF plane. The MdFO line angle is the intersection of the MdFO line with the MdF line, projected onto the MdF plane. The value is positive when the base of the

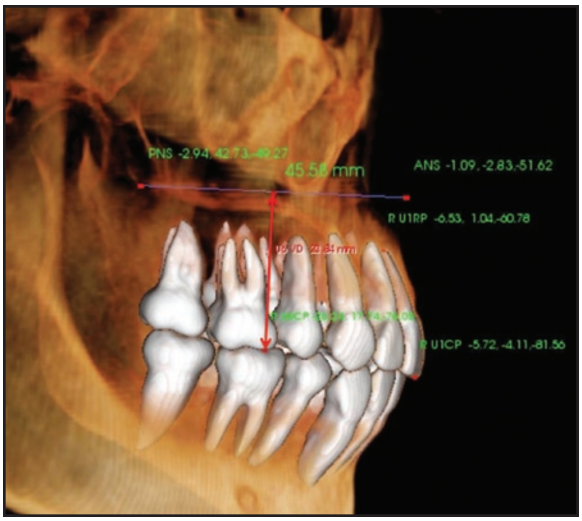

Fig. 10 Maxillary molar vertical development (U6VD).

angle is to the subject's right and diverges to the left, and negative in the opposite situation. Using these measurements, an occlusal cant can be readily determined as having a dental or skeletal origin, or a combination of the two. Skeletal asymmetries seen in the frontal plane have been previously described. Dental asymmetries are determined by measuring the distance from the RL U6CP to the maxillary plane. Differences between these two values indicate asymmetrical vertical development and positioning of the teeth. Likewise, the linear measurements from RL L6CP to the mandibular plane are used to detect abnormalities in the mandibular vertical dimension. This information may facilitate an assessment of asymmetrical vertical development of the dentition and thus improve diagnosis and treatment planning.

Occlusal Plane Inclination: MxSO Line Angle, MdSO Line Angle. The MxSO line angle is the intersection, if any, of the MxSO line with the maxillary plane, projected onto the MxS plane. The MdSO line angle is the intersection of the MdSO line with the mandibular plane, projected onto the MdS plane. The value is positive when the base of the angle is to the subject's posterior and diverges to the subject's anterior, and negative in the opposite situation.

Dental Transverse Analysis (Table 6)

Interdental width measurements are commonly used, especially in the mixed dentition, to evaluate the effectiveness of expansion or retention, and even to guide orthognathic surgery. These transverse measurements can readily be obtained from dental casts; while 2D lateral and frontal cephalograms can provide important estimates of tooth inclinations, they are often difficult to interpret because of the superimposition of structures. In contrast, 3D imaging allows accurate calculations to be made in any plane.

Transverse analysis of the dentition involves an evaluation of the tooth positions over the basal bone. This consists of linear measurements of the intercanine and intermolar widths, as well as an assessment of the molar inclinations relative to the apical base. Evaluation of molar position, which was seldom possible with 2D imaging, is essential for proper case diagnosis and outcome assessment. The linear distances between both the cusp tips and the apices are important indicators of crown positions over the root and the basal bone, and thus can help detect bodily or tipping movements during treatment. Information about the transverse dimension will aid in diagnosis of the skeletal and dental components of posterior crossbite.

Maxillary Incisor: RL U1FI, RL U1FP. Both angular and linear measurements are used to evaluate incisor positions in the frontal plane. The maxillary central incisor frontal inclination (U1FI) is the distal angle between the long axis of the maxillary central incisor and the MxF line, projected onto the MxF plane. The maxillary central incisor frontal position (U1FP) is the difference between the *x*-coordinate values of U1CP and ANS projected onto the MxF plane, indicating the transverse position of the maxillary central incisor crown within the maxilla.

Mandibular Incisor: RL L1FI, RL L1FP. The mandibular central incisor frontal inclination (L1FI) is the distal angle formed by the intersection of the MdF line and the long axis of the mandibular central incisor, projected onto the MdF plane. The mandibular central incisor frontal posi-

TABLE 6
DENTAL TRANSVERSE ANALYSIS

Measurement	Value	Type of Measurement
R U1FI	90.5°	Projected (Mx frontal)
L U1FI	87.0°	Projected (Mx frontal)
R U1FP	−3.5mm	Projected (Mx frontal)
L U1FP	5.0mm	Projected (Mx frontal)
R L1FI	86.0°	Projected (Md frontal)
L L1FI	87.0°	Projected (Md frontal)
R L1FP	−3.5mm	Projected (Md frontal)
L L1FP	2.0mm	Projected (Md frontal)
R U3FI	98.0°	Projected (L Mx oblique)
L U3FI	97.5°	Projected (R Mx oblique)
R U3FP	16.5mm	Projected (Mx frontal)
L U3FP	17.0mm	Projected (Mx frontal)
R L3FI	90.0°	Projected (L Md oblique)
L L3FI	93.0°	Projected (R Md oblique)
R L3FP	13.5mm	Projected (Md frontal)
L L3FP	12.0mm	Projected (Md frontal)
U3CW	34.0mm	Projected (Mx frontal)
U3RW	32.5mm	Projected (Mx frontal)
U3WR	1.04	Direct
L3CW	25.5mm	Projected (Md frontal)
L3RW	24.0mm	Projected (Md frontal)
L3WR	1.07	Direct
R U6FI	84.5°	Projected (Mx frontal)
L U6FI	83.5°	Projected (Mx frontal)
R U6FP	25.0mm	Projected (Mx frontal)
L U6FP	23.5mm	Projected (Mx frontal)
U6CW	48.5mm	Projected (Mx frontal)
U6RW	51.5mm	Projected (Mx frontal)
U6WR	0.94	Direct
U6MxWR	0.77	Direct
R L6FI	82.5°	Projected (Md frontal)
L L6FI	83.0°	Projected (Md frontal)
R L6FP	20.0mm	Projected (Md frontal)
L L6FP	17.5mm	Projected (Md frontal)
L6CW	37.5mm	Projected (Md frontal)
L6RW	43.5mm	Projected (Md frontal)
L6WR	0.87	Direct
L6MdWR	0.45	Direct

tion (L1FP) is the difference between the *x*-coordinate values of L1CP and Pog projected onto the MdF plane, indicating the transverse position of the mandibular central incisor crown within the mandible.

Maxillary Canine: RL U3FI, RL U3FP. The maxillary canine frontal inclination (U3FI) is the lingual angle formed by the long axis of the maxillary canine and the maxillary plane, projected onto the contralateral maxillary oblique plane. Using the MxF plane instead of the contralateral maxillary oblique plane will result in an underestimation of any changes in canine torque. The maxillary canine frontal position (U3FP) is the difference between the *x*-coordinate values of U3CP and ANS projected onto the MxF plane, indicating the transverse position of the maxillary canine crown within the maxilla.

Mandibular Canine: RL L3FI, RL L3FP. The mandibular canine frontal inclination (L3FI) is the lingual angle formed by the intersection of the R or L MdS line and the long axis of the mandibular canine, projected onto the contralateral mandibular oblique plane. The mandibular canine frontal position (L3FP) is the difference between the *x*-coordinate values of L3CP and Pog projected onto the MdF plane, indicating the transverse position of the mandibular canine crown within the mandible.

Maxillary Canine Widths: U3CW, U3RW, U3WR. The maxillary intercanine crown width (U3CW) is the distance between RL U3CP projected onto the MxF plane. The maxillary intercanine root width (U3RW) is the distance between RL U3RP projected onto the MxF plane. The maxillary canine width ratio (U3WR) is the ratio between U3CW and U3RW.

Mandibular Canine Widths: L3CW, L3RW, L3WR. The mandibular intercanine crown width (L3CW) is the distance between RL L3CP projected onto the MdF plane. The mandibular intercanine root width (L3RW) is the distance between RL L3RP projected onto the MdF plane. The mandibular canine width ratio (L3WR) is the ratio between L3CW and L3RW.

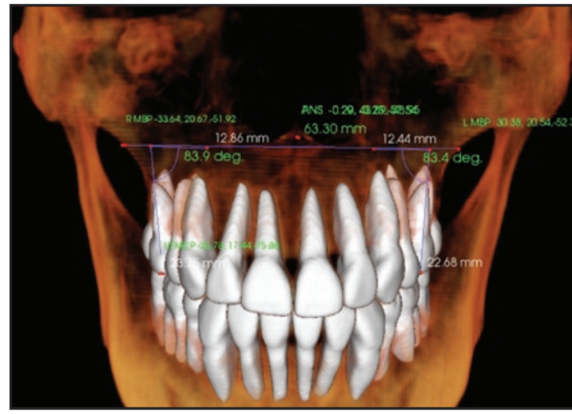

Fig. 11 Maxillary molar frontal inclination (U6FI).

Maxillary Molar: RL U6FI, RL U6FP. The maxillary molar frontal inclination (U6FI) is the palatal angle formed by the MxF line and the long axis of the maxillary first molar from U6CP through U6RP, projected onto the MxF plane (Fig. 11). The difference between the *x*-coordinate values of ANS and U6CP is the maxillary molar frontal position (U6FP), which indicates the transverse position of the maxillary first molar crown within the maxilla.

Maxillary Molar Widths: U6CW, U6RW, U6WR. The maxillary intermolar crown width (U6CW) is the distance between RL U6CP projected onto the MxF plane. The maxillary intermolar root width (U6RW) is the distance between RL U6RP projected onto the MxF plane. The maxillary molar width ratio (U6WR) is the ratio between U6CW and U6RW.

Maxillary Bone to Maxillary Molar Width Ratio: U6MxWR. As a comparison of the linear width of the dentition to that of the basal bones, the maxillary bone to maxillary molar width ratio (U6MxWR) provides useful information about the transverse development of the dentition relative to its skeletal base. The U6MxWR is the ratio between U6CW, the linear distance between RL U6CP projected onto the MxF plane, and MxBW, the linear distance between RL MxBP projected onto the MxF plane (Fig. 12).

Mandibular Molar: RL L6FI, RL L6FP. The

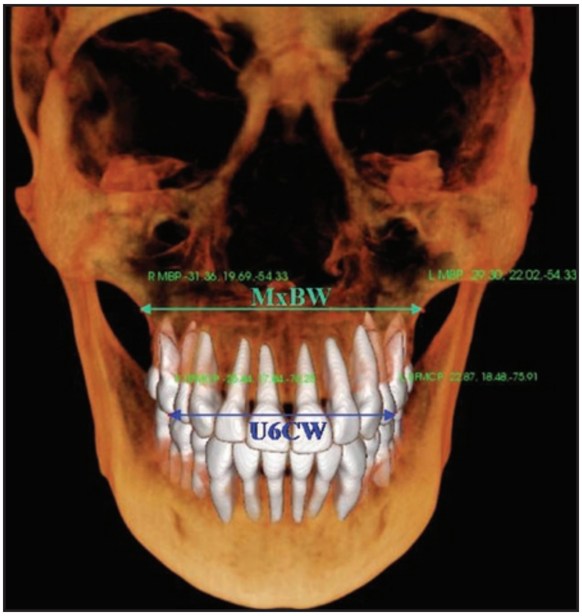

Fig. 12 Maxillary bone to maxillary molar width ratio (U6MxWR). (MxBW = maxillary bone width; U6CW = maxillary intermolar crown width.).

mandibular molar frontal inclination (L6FI) is the lingual angle formed by the MdF line and the long axis of the mandibular first molar from L6CP through L6RP, projected onto the MdF plane. The difference between the *x*-coordinate values of Pog and L6CP is the mandibular molar frontal position (L6FP), which indicates the transverse position of the mandibular first molar crown within the mandible.

Mandibular Molar Widths: L6CW, L6RW, L6WR. The mandibular intermolar crown width (L6CW) is the distance between RL L6CP projected onto the MdF plane. The mandibular intermolar root width (L6RW) is the distance between RL L6RP projected onto the MdF plane. The mandibular molar width ratio (L6WR) is the ratio between L6CW and L6RW.

Mandibular Bone to Mandibular Molar Width Ratio: L6MdWR. The mandibular bone to mandibular molar width ratio (L6MdWR) is the ratio between L6CW, the linear distance between RL L6CP projected onto the MdF plane, and MdBW, the linear distance between RL Go projected onto the MdF plane.

Discussion

Because the adult female patient analyzed here (Tables 1-6) was considered a good example of Class I malocclusion, her volumetric image was used to produce an initial set of measurements for this new 3D cephalometric analysis. Ongoing data collection from a wider sample of patients will provide useful means and normal ranges.

The 3D cephalometric analysis is based on many earlier 2D analyses and studies.[1-15] Limitations of 2D imaging include the superimposition of bilateral structural points, the magnification factor on a conventional cephalogram, and poor patient positioning. These limitations can make it difficult to determine whether a perceived asymmetry truly exists. In contrast, in the 3D analysis, the Cartesian coordinate system allows full visualization of any differences between bilateral structures. For example, differences between the right and left absolute values of the *x*-coordinates may suggest an asymmetrical position in the transverse dimension. Differences between the right and left absolute values of the *y*- and *z*-coordinates will indicate asymmetries in the anteroposterior and vertical dimensions, respectively.

The 3D analysis presented in this article has significant potential in the areas of diagnosis, treatment planning, and outcome evaluation. Because another important application of 3D imaging is the diagnosis of potentially serious sleep disorders, future studies are needed to develop a volumetric airway analysis. In any event, every 3D image should be reviewed by an oromaxillofacial radiologist.[33]

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ACKNOWLEDGMENTS: The author expresses his sincere gratitude to Dr. Stefan Alexandroni and Mr. Scott Frey for their help with the development of calculation formulas for the 3D cephalometric analysis. These are described in the Appendix, which appears in the online version of the article at www.jco-online.com. Drs. Joorok Park and Thao Nguyen provided outstanding contributions to the figures presented in this article, as well as editorial assistance. Thanks are also due to Dr. Jack Choi for his generous donation of the InVivoDental software and Dr. Ronald Redmond for his ongoing support of our school, including the donation of an iCAT machine, without which this research would have been impossible. Finally, the author thanks Dr. Robert Boyd for his administrative support for this project.

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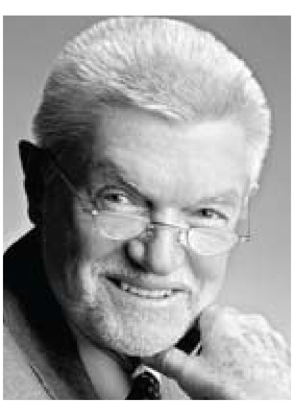
JCO INTERVIEWS

Dr. Rainer-Reginald Miethke on Orthodontic Treatment in Europe

DR. KEIM Reggie, how would you describe your treatment philosophy?

DR. MIETHKE My treatment approach is pretty much mainstream: I use a preadusted appliance with all typical adjuncts. I used to use a lot of headgears, including protraction headgears, but their application has decreased due to the lack of patient acceptance, the decline of extractions, and the availability of micro-implants. I still use functional appliances in the form of a headgear-activator combination, and also function regulators or other functional appliances. Moreover, I was the first user of Invisalign* in Europe and still treat a lot of my patients with the Invisalign system. As a typical European orthodontist, I believe in growth control, which means that some of my treatments start in the early mixed dentition. As far as extractions are concerned, I guess I am also a victim of the general trend toward nonextraction.



Dr. Miethke

Dr. Keim

Dr. Miethke is Professor and Chair, Department of Orthodontics, Dentofacial Orthopedics, and Pedodontics, Charité, Humboldt University, Berlin, Germany; a past President of the German Society of Orthodontics and the European Orthodontic Society; and Editor-in-Chief of the *World Journal of Orthodontics.* From 1986 to 2008, he was Editor-in-Chief of the journal *Praktische Kieferorthopädie,* now known as *Kieferorthopädie.* Dr. Keim is Editor of the *Journal of Clinical Orthodontics.*

DR. KEIM Can you elaborate on that last remark?

DR. MIETHKE Well, Bob, first of all we have to realize that we have a dramatic decline in tooth decay. We have less space loss, superb bone anchorage, many more non-compliance devices, bracket systems with lower friction—all these have contributed to the worldwide decline in extraction frequency. Even if secondary crowding is not the proper indication for extractions, we had to perform them in the past because of insufficient anchorage control, or we just did it to facilitate treatment. I was always interested in following my patients long after treatment, and, believe it or not, I saw a lot of stable results without disfigured faces. If I look at all the slides I took in these patients, I realize how short the treatment often was back then compared to today, where you struggle to get every last little bit of space. But parents and children object so strongly to extractions nowadays that I try to avoid them as much as medical conscience permits.

DR. KEIM Is this approach typical in German orthodontics?

DR. MIETHKE Treatment methods in Germany are probably somewhat generation-dependent, in the sense that the older generation still frequently uses removable appliances, whereas younger orthodontists most likely apply the same approach I

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described. Now, you might wonder why I am not like other members of the older generation, since chronologically I would belong to this group. The answer is that I was lucky to get some very good training at Louisiana State University from teachers like Jack Sheridan and from my late friend Jack Hickham. So I owe American orthodontics a lot. I will never forget that and will always be much obliged.

DR. KEIM Is the German system of health-care delivery different from that of other European countries?

DR. MIETHKE Yes, very much so. Europe is like a patch rug: its health-care systems are as different as its countries. The systems in some countries are very much the same as in the States, while in other countries the mandatory health insurance covers a large portion of orthodontic care.

DR. KEIM What differences do you see in the delivery of orthodontic care today between Europe and the United States?

DR. MIETHKE I guess orthodontics in general is more routine in the U.S. than it is in Europe. To me, it seems as if we on the old continent still have to convince parents again and again that their children need some kind of orthodontic treatment, whereas in the States, orthodontics is almost part of the physiological development process.

DR. KEIM What are the similarities?

DR. MIETHKE I believe that private participation in financing orthodontics is becoming more and more normal. With the official health-care system in Germany, everybody is eligible for open-heart surgery or an organ transplant. Since the system cannot cover smaller interventions, parents and patients now realize that they have to contribute.

DR. KEIM Has this changed over the last 10 to 20 years?

DR. MIETHKE Yes, this is a rather recent development resulting from a permanent cutback in public health-insurance coverage.

DR. KEIM Do you think that orthodontics is moving toward a global standard of care?

DR. MIETHKE Again, this is my personal opinion, but not mine alone, because I sought advice from others who are well aware of the European situation, like my friend, Dr. Wolfgang Schmiedel, President of the General Dental Council of Berlin. Yes, I think all European countries will move toward a global standard of care. This is due to the fact that we have outstanding lecturers who impart knowledge throughout the world. We have congresses all around the globe, and we have professional journals that are read across the continents, like JCO, which also has its readers in Germany.

DR. KEIM How do payment options for orthodontic treatment differ between the U.S. and Europe?

DR. MIETHKE Well, Bob, I do not know very much about your payment system, but I am somewhat familiar with the European one. This is because in 2002, Prof. Frans van der Linden, Dr. Schmiedel, and Dr. Ronald Bijlstra published a compilation of the various payment modalities in Europe (besides many other professional aspects). More detailed information is available at http://www.efosa.org/EFOSA_2003/index.php. Admittedly, the overview is not very recent, and things have changed since then—everything has declined all over the world. All in all, however, there is no better source of information than this website.

DR. KEIM Do you see differences in orthodontic philosophy across the countries of the European Union?

DR. MIETHKE Yes. I feel that in the Scandinavian countries, everything is very much the same as in the States. Germany and Austria apply the approach I have described as mine. In Holland, Belgium, and England, you may often find the Begg technique or its derivatives. But England seems to be a country where removables are also used in many patients (I hope this does not upset my English colleagues). What I said about removables is definitely true for the Eastern European countries.

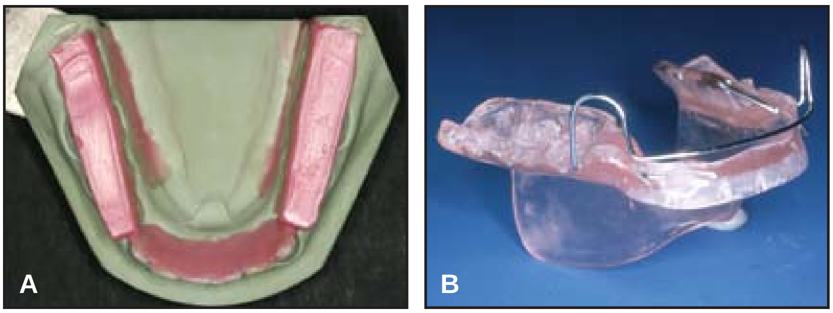

Fig. 1 A. Mandibular cast with waxed-out sections for activator fabrication; appliance body will contact only symphyseal gingiva, like lingual shield of function regulator. B. Finished activator with streamlined body, but sufficient tongue (function) space; labial bow does not contact incisors, but functions more like lip bumper. Small hooks are attached between lateral incisors and canines for application of anterior high-pull headgear. C. Headgear was personalized by patient with colored tape, indicating acceptance. Note: distance between cleat and sliding tube is too long (should be about 1").

DR. KEIM In general, are removable functionals such as the bionator and the function regulator becoming more or less popular?

DR. MIETHKE I am afraid they are becoming less popular. Why do I say I am afraid? Because I feel we are relinquishing all possibilities of influencing facial growth. Yes, I am familiar with the different studies demonstrating that functional appliances have little or no skeletal effect. But I have to say that these studies are not flawless for the following reasons: no two activators are alike, Class II is not one entity but a complex of many different configurations, facial growth can only be influenced when it really occurs, etc., etc. To conduct a study in which all these factors and many more are controlled seems more or less out of reach. Orthodontists should also be aware that only a very limited investment is required to achieve results that meet the needs of families with low budgets.

DR. KEIM Are Herbst** appliances now used more than headgear in the correction of Class II malocclusions?

DR. MIETHKE This answer can be very short: yes, definitely!

DR. KEIM Do you use them yourself?

DR. MIETHKE My honest answer is a very shy "no". Believe it or not, I did not really have a chance yet with my patients, or maybe I did not see the justified indication. So many of my patients come early enough that I can get really good results with an activator-headgear combination. In my older patients, I thought surgery was better indicated for a good profile change. But basically, I have no objections and will use a Herbst appliance in the next patient in whom I feel it is the best treatment option. In the department I oversee, quite a good number of patients are wearing a Herbst appliance, so it is not a matter of principle.

DR. KEIM What are the functional appliances that you use?

DR. MIETHKE I have different horses in my functional appliance stable. My workhorse is an activator-headgear combination (Fig. 1). This is an appliance that Jack Hickham introduced me to. The main characteristics are that the mandibular working cast is waxed out, so that the appliance

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Fig. 2 A. Patient with blocked-out maxillary left lateral incisor and maxillary midline shift to same side. B. Space gain after headgear was permanently tied in for four months. Headgear was actually secured only with thick elastics, which could easily have been cut in case of emergency, but patient believed it was permanently attached. C. Patient after treatment.

body contacts only the lingual symphysis, like a Fränkel lingual shield; the appliance body is reduced to a minimum, because a functional appliance should impede function as little as possible; and the headgear, mostly an anterior high-pull, is attached to hooks inserted between the canines and the lateral incisors to control vertical facial growth. As was pointed out as early as 1965 by Fred Schudy, there is an intimate relationship between the vertical and horizontal dimension, or effective mandibular length.[1]

In my stable there are also function regulators, my first choice in patients who have an Angle Class III and also a space-deficit problem, which I try to solve without extractions. The somewhat seldom-deployed horses are elastic open activators and bionators, which I choose when a treatment will last very long—for instance, in patients with delayed tooth eruption where cooperation will be the main problem. The appliance body should again be reduced as much as possible while still guaranteeing stability.

DR. KEIM In what age groups do you use these appliances?

DR. MIETHKE This aspect is most important, but still paid too little attention. First of all, I want my functional appliances only to have an orthopedic effect. That means I use them preferably in the (almost complete) early permanent dentition. That is the time around the pubertal growth spurt when the permanent canines and the premolars have erupted, so that their high cusps ensure a safe intercuspation. If there is little growth, the appliance has to be worn a long time, which increases the probability of dentoalveolar changes; plus, the low cusps of the first molars and the flat cusps of the deciduous posterior teeth cannot stabilize the occlusal correction.

DR. KEIM Do you really see orthopedic skeletal changes with your functional appliances?

DR. MIETHKE The answer is a qualified "yes". A prospective study of our activator-headgear-combination therapy in only 21 consecutive patients showed that this device has two-thirds skeletal and one-third dentoalveolar effect.[2] Of the two-thirds, however, only one-third is an advancement of the mandible and the remaining one-third a restriction of the maxilla. This is about 10% more skeletal effect than reported in other studies, in which, unfortunately, the differentiation between mandibular and maxillary effect is not described. A study on the function regulator type III in patients with mandibular prognathism showed that you can control the existing situation, but not really improve it.[3]

DR. KEIM What percentage of your patients cooperate with headgear treatment?

DR. MIETHKE In my early, heroic orthodontic years, I tied some headgears in permanently—of

Fig. 3 A. Severe rotations of both maxillary second premolars after previous extraction of first premolars by unknown practitioner. B. Overcorrection of both premolar rotations (right more than left) after treatment; patient was released without retainers. C. Proper positions of second premolars after 12 years without retention.

course, with the permission of the parents. This is when I learned how much you can accomplish with a headgear in an extremely short time (Fig. 2). Most of the headgears I use nowadays are cervical-pull headgears, which I utilize as orthopedic appliances to increase the vertical facial dimension. I emphasize the necessity of headgear application to both patients and parents from the first consultation on. Before I insert a headgear, I take the parents into my private office and tell them if they now make one negative remark, we can forget the whole procedure. Headgears are devices like eyeglasses and shoe lifts, which are also not negotiable. And I only request in-house wear, which is already a lot; anything more seems unrealistic to me. With these two prerequisites, I get almost 100% cooperation, which means they wear the headgear at least at night. My basic idea is to filter my patients before commencement of headgear therapy.

DR. KEIM What do you do if the patients fail to cooperate?

DR. MIETHKE To be honest, not much. First of all, I think I cannot replace the parents, whose responsibility it is to make their children go to school, see a doctor, and take a prescribed medication. I do not get upset, because my lifetime is limited, and what remains I like to enjoy. The only action I take is to talk to the patient in the presence of the parents and tell them that because of this cooperation failure, I can only accomplish a second-class result. The other option they have is orthognathic surgery. This serious information might help in about 50% of the non-cooperative patients.

DR. KEIM Do you believe in overcorrection of Class II correction or rotations?

DR. MIETHKE My answer is manifold. In an orthodontically corrected Class II, I would say "no", supposing the teeth have high, well-defined cusps, the occlusion is well settled, and there is no Sunday bite, which has to be checked for carefully. If the cusps are small and attritioned, the occlusion is not well settled, and there is a big CR-CO discrepancy, I think we get the short end of the stick anyway. If the Class II will be surgically corrected, I have to entrust this option of overcorrection to a certain degree to the surgeon. When it comes to rotations, my answer is "yes, yes, yes" (Fig. 3). That is one of the reasons I like indirect bonding so much, because there you have the chance to fine-tune your overcorrections (I even used Tom Creekmore's Slot Machine for this purpose). Finally, this is one of the good features of Invisalign—that you can plan for overcorrections, assuming the rotations occur in the first place.

DR. KEIM What appliance do you favor for adult treatment?

DR. MIETHKE I favor "invisible" braces. For me, this is mainly Invisalign and Crozat appli-

Fig. 4 A. Anterior spacing in adult patient who requested "invisible" braces before development of Invisalign. B. Clear buttons bonded to four maxillary incisors, which were retracted and intruded with elastic attached to lever arms of Crozat appliance (note cribs on first molars). C. Patient after treatment.

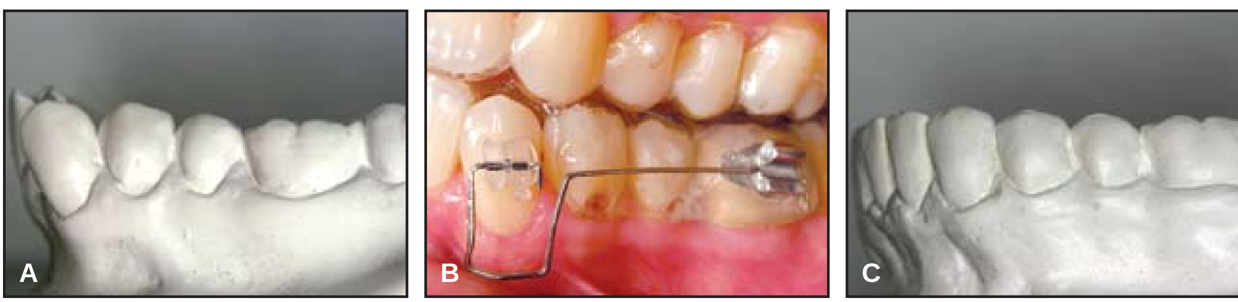

Fig. 5 A. Position of mandibular left canine before Invisalign treatment. B. After Invisalign treatment, customized splint is fabricated with clear canine bracket and molar attachment. Lingual and occlusal canine region is waxed out on working cast to upright and extrude this tooth with programmed lever. Patient inserted and removed spring with mosquito forceps. C. Position of canine after auxiliary treatment; more extrusion would have been desirable, but was not permitted by occlusion.

ances (Fig. 4). I like Crozats a lot; especially in combination with clear buttons and elastics, one can get surprisingly good results. The biggest problem with Crozat appliances is fabrication—you need a good, experienced lab, which is not so easy to find because these appliances are too seldom ordered. To me, invisible braces are easier accepted, because they interfere very little with social life. Many adult patients had orthodontic treatment earlier, so their occlusion is good, but they just want to get rid of some crowding or spacing, and any fixed appliance is almost overkill. Also, many of these patients have artificial tooth surfaces, on which bonding is not easy. Many times the result of such invisible therapy is not as perfect as with fixed appliances. But when you have already accomplished some remarkable improvement, patients are much more inclined to accept a few clear brackets. A few are always enough, because the last aligner is used with a cutout to prepare all the necessary anchorage (Fig. 5). With Invisalign, there is one more advantage: patients can see beforehand the course of treatment and the end result, they can discuss it with us, and we can change it when reasonable. I am afraid we are such dedicated professionals that we have no idea how limited the dental knowledge and imagination of our patients are.

DR. KEIM Has the use of temporary anchorage devices become mainstream in Europe?

DR. MIETHKE Absolutely—for the younger generation and also for the open-minded "best-agers". Do not forget that somebody like the Chairman of Orthodontics at the University of Mainz, Dr. Heinrich Wehrbein, was one of the first to gain clinical experience with these devices.[4] As one of the good-agers, I use TADs, too, as you know by my answer to your opinion poll (JCO, September

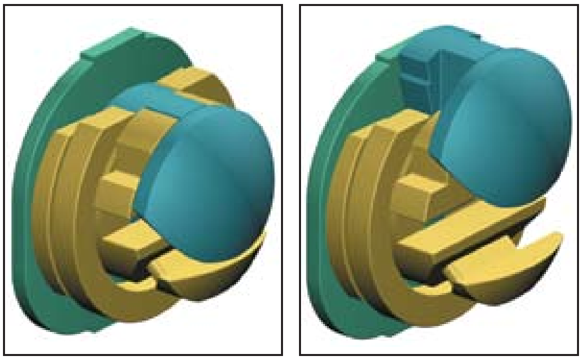

Fig. 6 Edgelok bracket in closed and open positions. (Images courtesy of Strite Industries.)

Fig. 7 In vivo friction test.[6] Maxilla is fixed in custom-cast splint, leaving mandible free. Testing machine pulls straight wire with preadjusted angulation and inclination through bracket on central incisor of spaced dentition. Whenever patient occludes, friction is immediately and markedly reduced.

2008). By the way, TADs can also be very helpful in combination with Invisalign treatment.

DR. KEIM In what types of cases have you used miniscrews?

DR. MIETHKE In patients in whom I needed to intrude teeth or move them distally. This includes Invisalign cases in which I tip posterior teeth distally to shorten the lengthy period of moving them with aligners.

DR. KEIM Is cone-beam computed tomography used much in Europe?

DR. MIETHKE Not yet, because it is still quite expensive, and insurance pays for it more or less only in exceptional patients, like those with cleft lip and palate or severe disfigurations.

DR. KEIM Have self-ligating bracket systems been widely accepted?

DR. MIETHKE Self-ligating bracket systems are becoming more and more popular. This is due to several factors, not least among them being marketing by companies and also by some very talented gurus. To me, this is rather hilarious, because in 1978 Jack Hickham introduced me to Edgelok*** self-ligating brackets (as developed by Jim Wildman), which I hated at first and loved in the end. They were exceptional (Fig. 6). Wherever Jack lectured, he advocated these brackets, as I did later on when I entered the lecture circuit. But obviously neither of us were gurus; we could not convince anybody to buy them, and sales with these brackets were so marginal that Ormco gave up producing them. My point is that I personally liked and still like self-ligating brackets very much for various reasons. What I do not like is the frenzy, the fact that they are presented as something completely new, as objects with almost magical qualities that have not been proven, although these brackets have been in use for some time. Allow me one last word: unfortunately, these brackets are not "self-ligating", but, at best, "ligation-free".

DR. KEIM Don't these brackets reduce friction?

DR. MIETHKE Honestly, Bob, I do not know. Let us face the fact that there are at least four different methods for testing friction, including fixed angulation/inclination, varying angulation/inclination, and computer simulation, as developed by Prof. Dieter Drescher from the University of Düsseldorf.[5] These three are in vitro tests, but it seems much more reasonable to test friction intraorally, as attempted by only a few researchers so far (Fig. 7). Influencing factors other than those mentioned above include brackets (material, mesiodistal width, occlusogingival height, slot refine-

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ment), archwires (material, cross-section, size), type of ligation, interbracket span, force application point, tooth mobility, and environmental setting. My point is that any given friction result is only true for the conditions under which it was tested. Let us also make the following clear: nowhere in the mouth does a wire slide through a bracket slot, but a tooth slides along an archwire. That is why even intraoral experiments are only an approximation to the truth.

Two more things: I do not understand why ligation-free brackets are always tested against brackets in which the archwire is secured with AlastiKs.† Every knowledgeable orthodontist will use very lightly tied steel ligatures at the start of leveling. Also, we should never forget that friction has a Janus face: it makes moving teeth more difficult, but we also need teeth which do not move because they are one of our principal sources of anchorage.

DR. KEIM What is the current status of surgical-orthodontic treatment in Europe?

DR. MIETHKE I would say we have quite a large number of skillful maxillofacial surgeons who produce stable, high-quality results that fulfill standard criteria. This is very good because a growing number of patients are seeking combined therapy. The reason is that insurance policies often have clauses covering treatment costs for such patients. This approach seems reasonable because, with these complex therapies, a patient's malocclusion is usually quite severe.

DR. KEIM What is your opinion of "surgery first", as demonstrated in the February JCO[7]?

DR. MIETHKE I like it a lot and agree completely with the authors. In the past, I had patients with an extreme anterior crossbite in whom it was almost impossible to upright the mandibular incisors sufficiently because of the strain of the lower lip—besides all the other problems described in the Nagasaka article. Myself, I have limited experience with surgery first only in Class III patients, but all of them are absolutely positive. I am happy our maxillofacial surgeons are very open-minded when it comes to this procedure.

DR. KEIM Do you feel that early treatment is more common in Europe than in the U.S.?

DR. MIETHKE I think it is much more common. Maybe some of the procedures our orthodontists perform would be delivered by pedodontists in the States. In many European countries, we have no specialized pedodontists. So if the family dentist sees a problem which requires preventive or interceptive orthodontic measures, she or he would refer the patient to an orthodontist, who will take care of the condition. Could it be that, in general, U.S. orthodontics is more mechanically oriented than European orthodontics, with its growth and development orientation?

DR. KEIM Is serial extraction still practiced in Europe?

DR. MIETHKE Considering our discussion about extractions, I guess it is practiced less and less. Again, though, I wonder whether this is good or bad. First of all, I treated one of my daughters with serial extraction and nothing else. Her dentition came out perfectly straight, with one little space between the canine and second premolar on the left mandibular side. And she has a pretty face—at least in her dad's eyes. Second, who can be sure that third molars are not being removed more and more often instead of the premolars, which would normally be sacrificed during serial extraction? Besides, from all I have heard, wisdom tooth removal is no fun. But your question should actually trigger a study of the type that is frequently done by JCO.

DR. KEIM What are the major trends in orthodontic clinical research in Europe?

DR. MIETHKE I see that Europeans publish in professional journals all around the world, just as Americans publish in European periodicals. But I would like to draw your attention to one aspect. A

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Fig. 8 A. Patient wearing Copyplast‡ splint retainer with both maxillary left premolars cut out to promote extrusion and settling. B. Dr. Miethke wearing Imprelon‡ splint retainer; stiffer material makes cutouts somewhat more difficult. C. Fixed retainer does not allow flossing, making plaque accumulation more likely, and does not guarantee stability (photo courtesy of Dr. Vittorio Cacciafesta).

very recently published Health Technology Assessment stated that orthodontics has no benefit for a patient's health.[8] I do not want to go into details of this report. But it caused the chairpersons of the German dental schools to initiate a prospective multicenter study on this problem. I feel it would be good for orthodontics as a whole if such data would emerge.

DR. KEIM What do you believe contributes to the stability of treatment results?

DR. MIETHKE Number 1 would be a perfect alignment, where the teeth were moved only within the dentition-surrounding envelope of relaxed and active muscle tone. In other words, I learned from my mentors to keep the archform as constant as possible, I followed their example, and I think this served me well. This means that I still reshaped every archwire on the base of a Brader template (it could also be a different template, though it had to come in different sizes and widths). Second, and at least as important, is normal orofacial function—and this includes a physiologic function of the tongue, lips, and cheeks (including nose breathing and absence of parafunctions) without any habits. Finally, in my opinion, cessation of growth contributes to the stability of our treatments—though, unfortunately, it sometimes occurs very late, especially in those Class III patients where we need it most badly.

DR. KEIM What about canine guidance?

DR. MIETHKE I still attempt to establish a solid canine guidance, since, according to several studies, this will lower the muscle activity and thus the loading of the dentition during parafunctioning. I know there is no scientific proof that canine guidance is superior to any other form of occlusion, but then again, canine guidance is almost inevitable if all teeth are well aligned—in other words, all their physiologic contact points are tangent to one another.

DR. KEIM Do you believe in the concept of permanent retention?

DR. MIETHKE Yes, everything is constantly changing in our body; why should our dentition not adjust, too? My favorite mode, however, is aligner-like splint retainers (Fig. 8).

DR. KEIM Why do you prefer splint retainers?

DR. MIETHKE They do not interfere with flossing. They allow slight corrections or overcorrections. They protect the occlusion from attrition, which is more and more frequent in our times with stress from various circumstances. Attrition will not only destroy the teeth, but is the consequence of parafunctions. These splint retainers protect the occlusion from parafunctions, which will release the "anterior component of occlusal force", as

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Southard described it.[9] According to him—and I follow his line of thinking—this can be one cause of relapse of anterior crowding and malalignment. This is not to say that I would not place a fixed 1-1 retainer in a patient with a maxillary midline diastema or an intracoronal splint fixation in a periodontally compromised patient with highly mobile teeth. But to make doubly sure, I would even place splint retainers in these patients.

DR. KEIM On behalf of our readers, I'd like to thank you for your candid and enlightening remarks.

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Effectiveness of a Compliance Indicator for Clear Aligners

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Patient compliance is crucial in orthodontic treatment involving removable appliances. This is especially true for adult patients, who have no growth remaining to help compensate for poor cooperation. The orthodontist's ability to predict a given individual's level of compliance is also important, because patients who are not expected to be cooperative may be better treated with fixed rather than removable appliances. Studies have shown no association, however, between patient cooperation and such factors as quality of life, socioeconomic status, and educational level,[1-3] although females have been found to be generally more compliant than males.[4] Assessing cooperation is equally challenging: a study of the reliability of patient reports and clinicians' ratings of compliance found that neither had an accuracy rate of more than 43%.[5]

Attempts to improve compliance through behavior modification using a reward system have yielded mixed results; although such efforts have been found to have a positive effect on patients who were already more compliant than average, they had little effect on patients with below-average cooperation.[6] The degree of patient motivation and the rapport between the patient and the orthodontist seem to be more significant.[7,8]

Align Technology recently introduced a "compliance indicator" for teen-agers being treated with the Invisalign system.* Although patients are generally required to wear each set of the clear

*Registered trademark of Align Technology, Inc., 881 Martin Ave., Santa Clara, CA 95050; www.aligntech.com.

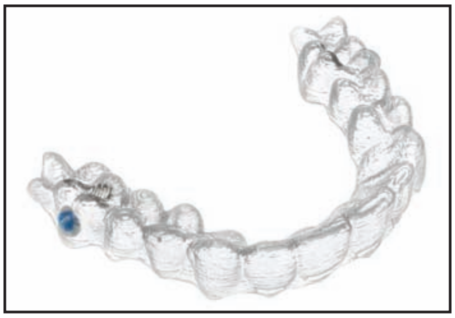

Fig. 1 Aligner with encapsulated color compliance indicator.

Dr. Tuncay **Dr. Bowman** **Dr. Nicozisis** **Dr. Amy**

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Align Technology, Inc. **Non-Adult Comprehensive Treatment Study**

Subject ID **Subject Initials**

Site#________ ________ ___________

Patient Aligner Wear Diary

Please fill out how many hours you wore your aligners each day

Aligner use diary: **Aligners are to be worn at all times, except when eating, drinking, and brushing teeth. Please record below the amount of time you wore your aligners each day.**

Week 1

Day	Hours Worn
1	
2	
3	
4	
5	
6	
7	

Week 2

Day	Hours Worn
1	
2	
3	
4	
5	
6	
7	

Week 3

Day	Hours Worn
1	
2	
3	
4	
5	
6	
7	

Week 4

Day	Hours Worn
1	
2	
3	
4	
5	
6	
7	

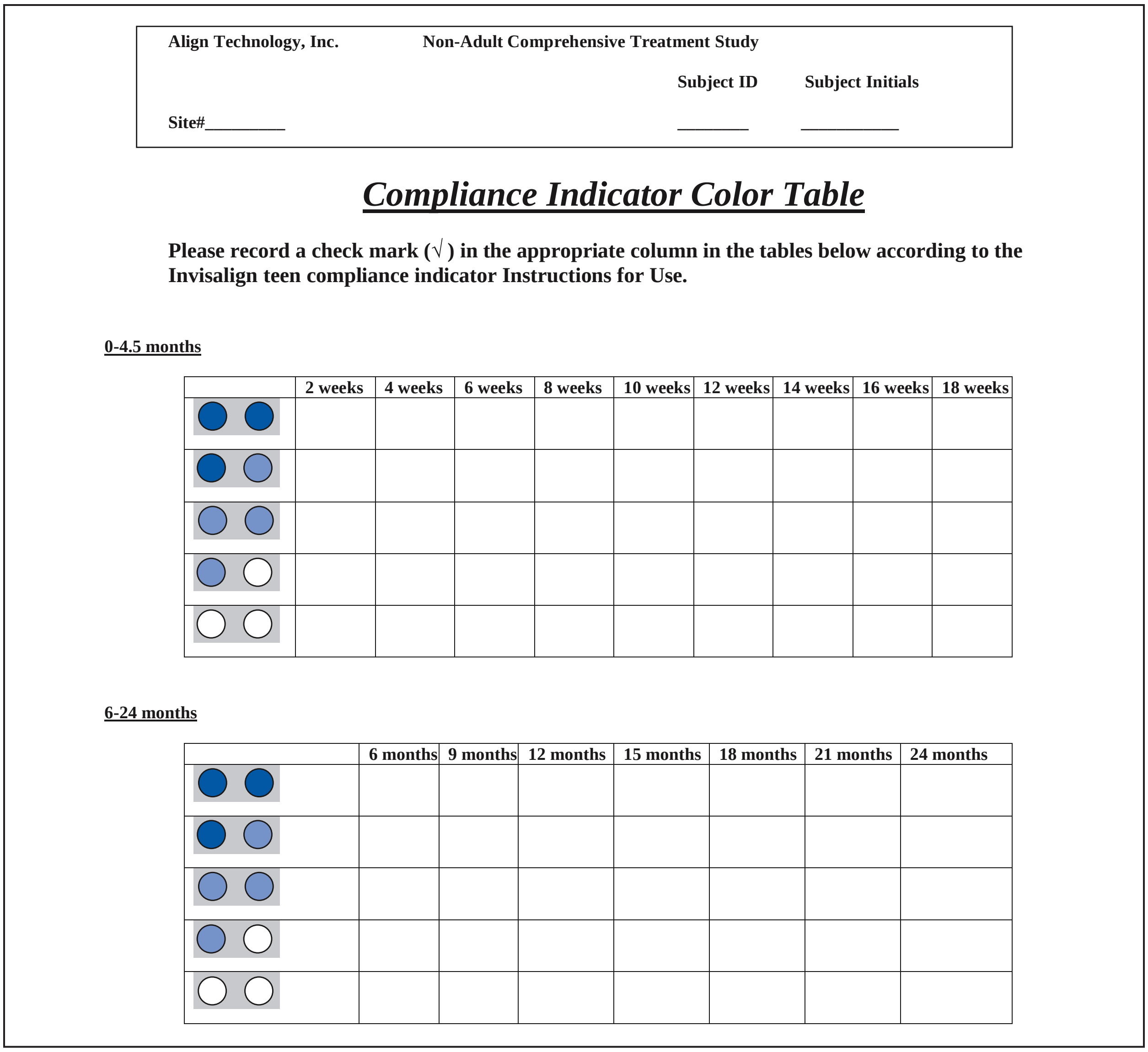
Fig. 2 Aligner wear diary to be completed by patient.

removable aligners for a total of 300-400 hours, it has been impossible to monitor their actual wear time until now. This article reports the results of a study measuring the clinical effectiveness of the compliance indicator over a three-month period.

Materials and Methods

The study sample consisted of 14 patients (five females, nine males) who were participating in a larger, ongoing prospective clinical study on clear aligner treatment in teen-age patients. That study involves patients in four private practices, located in Kalamazoo, Michigan; Princeton, New Jersey; Oklahoma City; and Philadelphia. Parents who allowed their children to participate in the present study were given fee discounts of approximately 20%, and patients who kept every study-related appointment were rewarded with gift certificates. Written informed consent was obtained from all patients and their parents before enrollment in the study.

The 14 patients in the study were given Invisalign clear aligners with compliance indicators made of encapsulated, food-grade dye embedded in each posterior segment, usually of the upper



Align Technology, Inc. Non-Adult Comprehensive Treatment Study

Subject ID Subject Initials

Site#_________ ________ ___________

Compliance Indicator Color Table

Please record a check mark (√) in the appropriate column in the tables below according to the Invisalign teen compliance indicator Instructions for Use.

0-4.5 months

	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	16 weeks	18 weeks

6-24 months

	6 months	9 months	12 months	15 months	18 months	21 months	24 months

Fig. 3 Compliance indicator color table to be completed by orthodontist or staff. Left column of colored dots refers to "slow" dissolution indicator; right column is for "fast" dissolution indicator.

aligner (Fig. 1). The dye fades from dark blue to clear over the 300-400 hours of recommended wear during a two-week period. Each aligner contains two different formulations, with "fast" and "slow" dissolution rates to account for variations in salivation.

The daily and total number of hours of prescribed aligner wear varied slightly according to the patient's individual treatment plan, but each set of aligners was worn for the prescribed two weeks. Each patient recorded his or her daily aligner wear time on a form distributed at the beginning of the study (Fig. 2). The patients wore a total of 84 sets of aligners during the 12-week period, but 34 sets were excluded because some patients did not consistently record the number of hours of wear on the daily log, leaving 50 sets in the study. Two patients were dropped from the study due to incomplete patient logs.

Patients turned in their used aligners for evaluation of the compliance indicator colors, and a table was used to record the colors of each pair of indicators, with possible combinations ranging from dark blue/dark blue to clear/clear (Fig. 3). To eliminate clinician bias, the aligners were also sent to Align Technology for a blind recording of the degree of color fade.

Results

The color changes recorded for the compliance indicators correlated with the number of

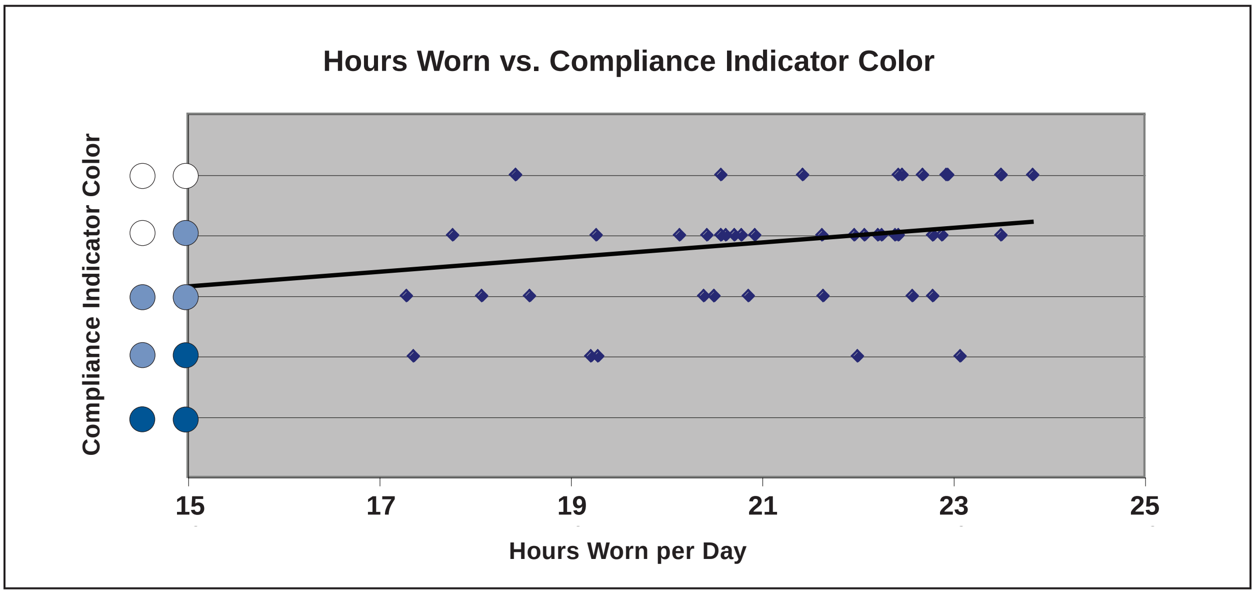


Fig. 4 Correlation of compliance indicator color with number of hours of wear per day reported by patients ($R^2 = .083$).

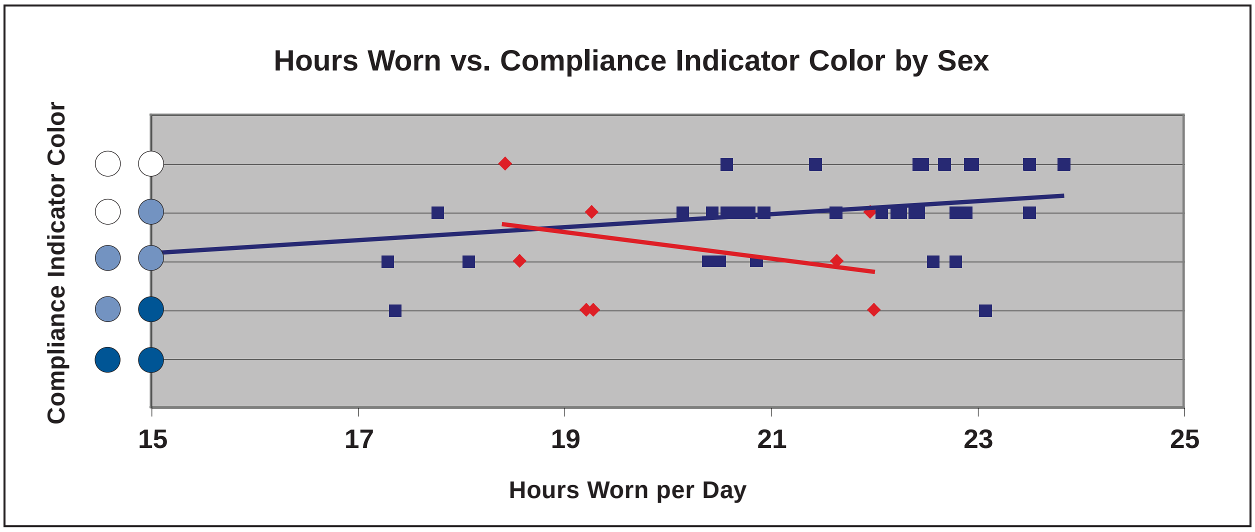


Fig. 5 Correlation of compliance indicator color with number of hours worn per day by sex (blue = male patients, $R^2 = .135$; red = female patients, $R^2 = .116$).

hours of wear recorded by the patients (Fig. 4). A stronger correlation was found, however, between compliance indicator color and the number of hours of reported wear for male patients than for female patients (Fig. 5).

Discussion

Specific intraoral devices designed to assess the compliance of orthodontic patients with removable appliances have generally produced disappointing results. For example, timers used to monitor headgear wear have served more to police compliance than to enhance it. When patients are informed that their headgear wear time is being electronically monitored, they tend to wear the headgear more than other patients do, but still not as much as instructed.[9] Typically, patients significantly overreport their headgear wear.[10] Another approach intended to help estimate the wear time

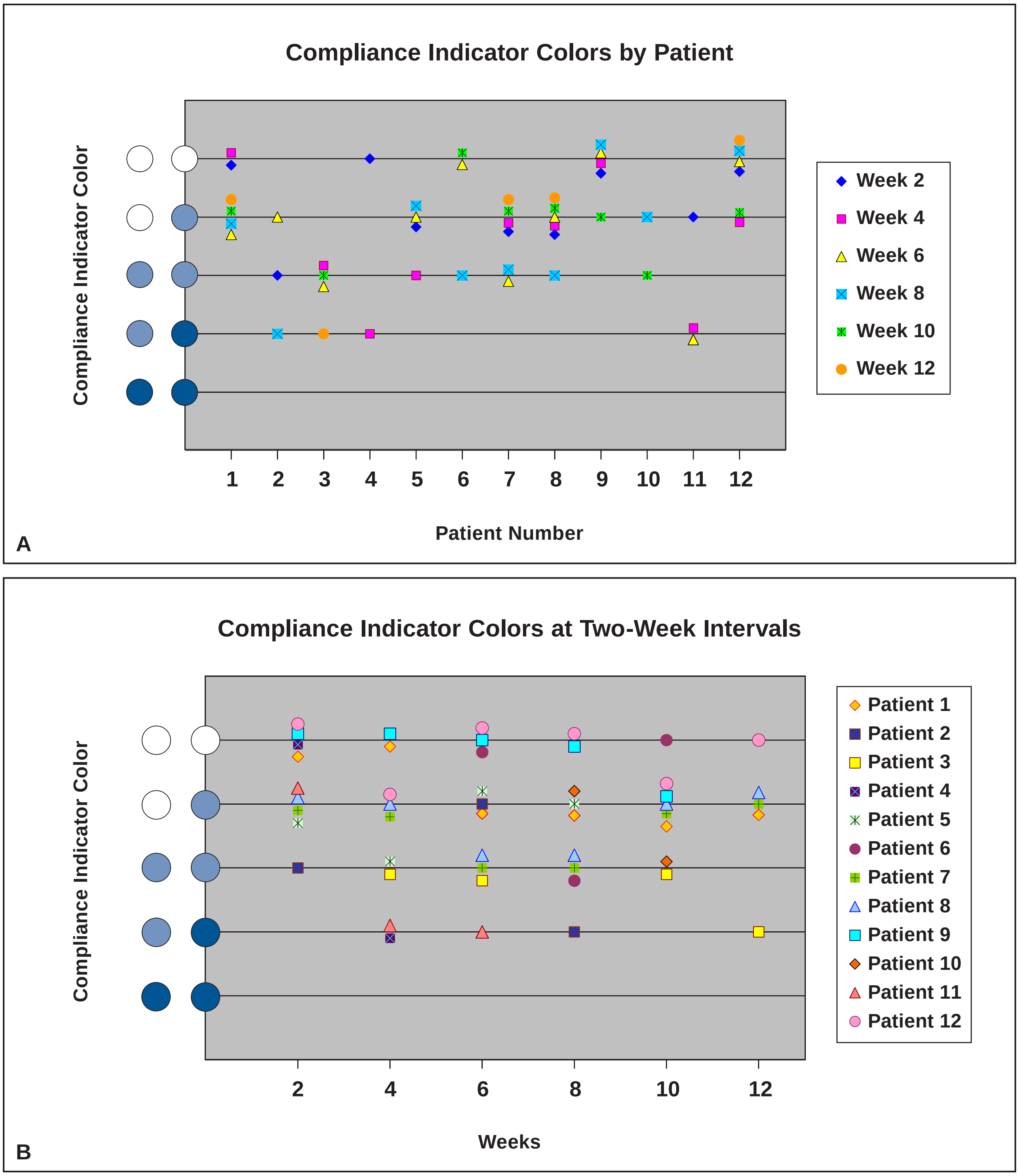


Fig. 6 A. Compliance indicator colors by patient. B. Compliance indicator colors by patient at biweekly intervals, up to 12 weeks of treatment.

of removable appliances—measuring the dissolution rate of water-soluble glass rods placed in molar tubes—was found to be inaccurate.[11]

The recently introduced Smart Retainer** uses an electronic reader to record the amount of time the retainer is worn.[12] Preliminary data indicate that this device, which is similar to the previously introduced headgear timing devices, is effective in improving patient compliance. Nevertheless, it is based on the same concept of policing patient cooperation. Although this may be effective to some degree, we believe that the continual monitoring and feedback permitted by the compliance indicator for clear aligners may be better accepted and thus more effective in achieving compliance, especially in older patients. The use of color fading to indicate duration of use or wear of intraoral devices is not new; a similar approach is used in Oral-B manual and electric toothbrushes*** to remind the user when to switch to a new brush or brush head. With the aligner indicator, patients can participate in monitoring their own wear time by checking the color themselves.

The possibility that patients in our study tried to fool the system, as was sometimes done with the headgear timing devices, seems unlikely because the results were consistent across the study subjects and in all centers. Moreover, the manufacturer's laboratory evidence suggests that due to the high molecular weight of the polyvinyl alcohol material used to encapsulate the food-grade dye, the blue coloring will remain embedded unless exposed to moisture and temperatures greater than or equal to body temperature. Therefore, the color will not fade in a glass of cold water, but could be affected by submersing the aligner in extremely hot water for some time. Of course, at temperatures that high, the aligner itself would be distorted to the point of being unusable. The laboratory data suggest that the color does not change when used with Invisalign cleaning crystals, because the water used to dissolve the crystals at the bathroom or kitchen sink would be merely lukewarm.

In our study, each patient tended to have a consistent amount of indicator color fade from one set of aligners to another (Fig. 6). Therefore, any deviation from this "baseline" color fade over the course of treatment could prompt the orthodontist to discuss the issue of compliance with the patient. Checking the color indicators on the used aligners every two weeks confirms that the patient is wearing the appliances as instructed.

The results of our study demonstrate that the color compliance indicator has considerable promise for improving the efficiency and effectiveness of orthodontic treatment with clear aligners.

**Scientific Compliance, 3575 Piedmont Road, Suite 1040, Atlanta, GA 30305; www.scicomply.com.

***Oral-B Consumer Services, 1 Gillette Park, South Boston, MA 02127; www.oralb.com.

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CASE REPORT

Focal Sclerosing Osteomyelitis and Orthodontic Treatment Planning

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Orthodontic tooth movement is based on the response of the supporting periodontium and alveolar bone. Any abnormality in these underlying structures can affect tooth movement and therefore should be considered in treatment planning.

This article describes orthodontic treatment of a patient with a mandibular bony osteosclerotic lesion that negatively affected the progress of treatment and the final result.

Diagnosis

A 33-year-old female presented with a mild Class III malocclusion (Fig. 1). Many years earlier, the maxillary left canine and the mandibular left first permanent molar, right second premolar, and right second molar had been extracted.

X-rays revealed a circumscribed, radiopaque lesion with a faint radiolucent margin near the site of the extracted mandibular right second molar, at the level of the root apex. The finding was evaluated by a maxillofacial surgeon. Because the lesion was located near an extraction space, it was thought to be related to long-term infection of the extracted tooth. The preliminary diagnosis was condensing osteitis, also known as focal sclerosing osteomyelitis, caused by either odontogenesis or the hematogenous spread of a low-grade infection. Because the lesion was asymptomatic, however, no surgical intervention was planned.

Treatment Progress

Orthodontic treatment was undertaken to correct the patient's anterior crossbite through retraction of the mandibular anterior teeth. The residual spaces were closed and the molar roots uprighted, but the posterior teeth were protracted (Fig. 2). Because a high degree of resistance was encountered, molar uprighting took longer than expected. Total treatment time was 35 months.

Post-treatment radiographic evaluation showed contact between the mandibular right third molar root and the radiopaque bony lesion, with concomitant apical and lateral resorption of the mesial root (Fig. 3), although the bony lesion was noticeably smaller than in the pretreatment x-rays. A computed tomographic scan of the mandible was performed to confirm that the apparent resorption was not due to superimposition of the lesion and the root; the resulting image clearly showed resorption of the third molar's mesial root (Fig. 4).

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Dr. El-Beialy


Dr. Mostafa

Discussion

Focal sclerosing osteomyelitis is considered the most common cause of periapical radiopacity in adults, appearing in 6-8% of all dental radiographs.[1,2] Women are more frequently affected than men.[2] Some 85% of these lesions occur in the mandible, predominantly in the first molar regions.[3,4] In a young adult, the condition often affects the periapical bone around a carious tooth with pulpal involvement.[1,4]

The higher frequency of focal sclerosing osteomyelitis in the mandible than in the maxilla is related to both physiological and anatomical factors. The mandible is less highly vascularized than the maxilla, with less collateral circulation. Moreover, the dense mandibular cortex prevents drainage of an infection. The chronic nonsuppurative, sclerosing form of osteomyelitis is a response to a chronic low-grade infection of the medullary bone.[4]

Radiographically, the condition is frequently observed at the roots of a mandibular molar or premolar with infected pulp.[1,4] In the medullary region, a circumscribed mass of isolated bone will appear more radiopaque than the surrounding bone; the margins may be distinct or poorly defined.[4,5] When these focal sclerotic lesions are asymptomatic, however, surgical treatment is unnecessary.[4]

Of primary concern to orthodontists is the lack of microcirculation and viable bone cells in the sclerotic area.[5-7] Because effective tooth movement depends on an adequate blood supply to the tissues, sclerotic areas will respond abnormally to orthodontic forces, possibly preventing normal bone remodeling. Thus, an avascular, hyalinized bony lesion in the line of tooth movement can lead to root resorption.[5,8]

In our experience, this condition is not rare in orthodontic cases. Radiographs of another patient, a 28-year-old male, revealed isolated bony lesions surrounding both mandibular second premolars (Fig. 5); mesial or distal movement of either tooth

Fig. 1 33-year-old female patient with mild Class III malocclusion before treatment.

Fig. 2 Mandibular right third molar during space closure and molar uprighting.

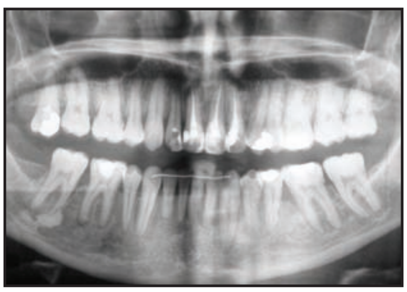

Fig. 3 Post-treatment radiograph, with close-up of mandibular right third molar showing apical and lateral resorption of mesial root.

would have jeopardized the integrity of the root. A patient's medical history, including chronic low-grade infection, should always be considered in conjunction with pretreatment radiographic evaluation.

ACKNOWLEDGMENTS: The authors would like to thank Drs. Sherihan Hasan and Lobna Tawfik for their assistance with the production of this manuscript.

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Fig. 4 Three-dimensional computed tomographic image of mandibular right third molar, showing mesial root resorption.

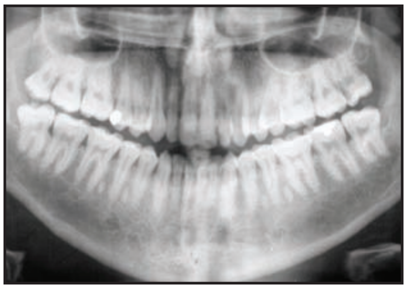
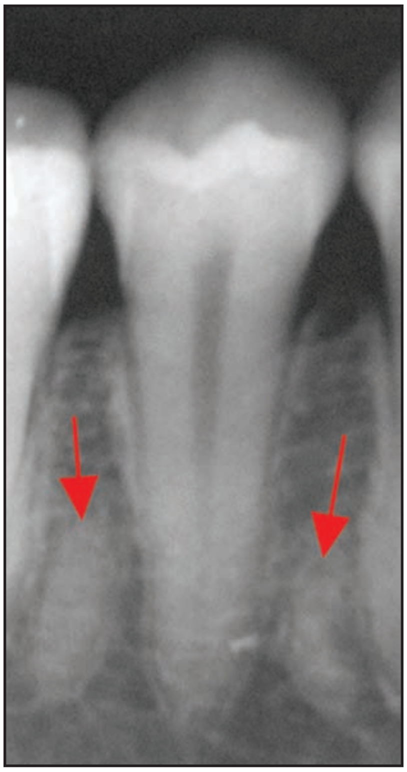


Fig. 5 28-year-old male patient with isolated osteosclerotic lesions surrounding both mandibular second premolars.



PEARLS

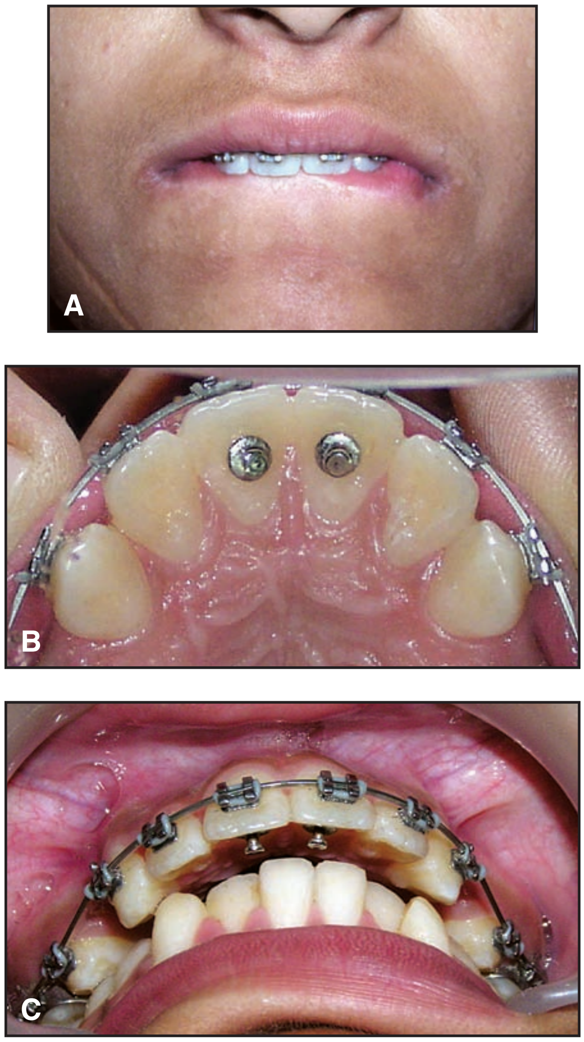
(Editor's Note: If you have a clinical or practice management Pearl to share with your colleagues, send it to JCO, 1828 Pearl St., Boulder, CO 80302. Appropriate illustrations are welcome; a photograph of the author and a copyright transfer form are required prior to publication.)

Lingual Buttons to Intercept Lip-Sucking Habits

To treat a lower-lip-sucking habit (A), we bond metal buttons* to the lingual surfaces of the upper incisors (B). The buttons should be placed to avoid interference with the occlusion and with oral hygiene (C). Although they are comfortable, with smooth, rounded edges, they remind the patient not to suck the lower lip. For patients with especially intense habits, we bond buttons to all the upper anterior teeth.

Bonded buttons avoid the shortcomings of other appliances used for this purpose, such as oral screens, lingual arches with soldered cribs, and lip bumpers. Our technique has the following advantages:

- Lingual buttons are less bulky and more esthetic.
- No laboratory procedures are required.
- Bonding is quick and easy.
- Fixed appliance therapy can be carried out simultaneously.



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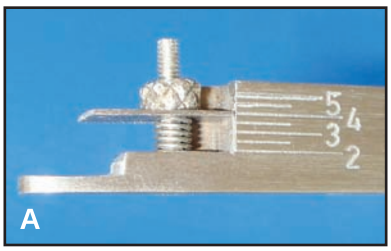
CLINICAL AID

A New Tool for Orthodontic Bracket Placement

McLaughlin and Bennett have designed gauges to measure bracket heights according to their bracket placement chart.[1] Metallic or wooden jigs are available for bracket heights ranging from 2mm to 5.5mm from the incisal or occlusal edges, with each jig having a bracket placement gauge on each end. These are cumbersome to use, however, and have to be interchanged frequently during the bonding procedure, causing considerable loss of chairtime.

Ankur's Bracket Jig* (ABJ) replaces these separate jigs with a single tool consisting of an incisal/occlusal arm with an engraved millimetric ruler, a vertical screw, a spring, a horizontal bracket-engaging arm, and a nut to hold the bracket arm in place over the spring (A). Bracket heights from 2mm to 5.5mm can be set by rotating the nut clockwise or counterclockwise with the thumb (B), thus moving the horizontal arm downward or upward (C).

This all-in-one tool eliminates the need for multiple bracket placement gauges, thus saving chairtime and improving practice efficiency.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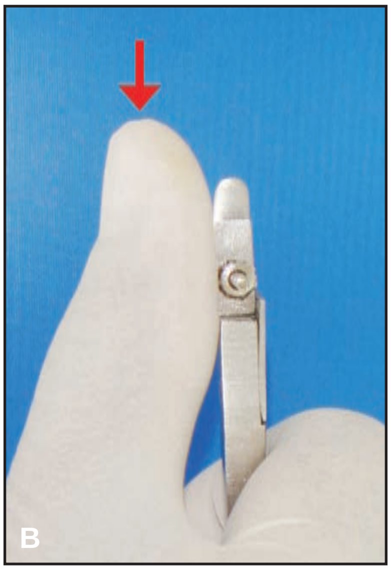
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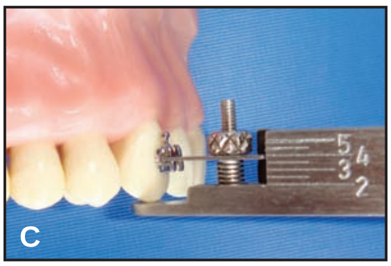
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